This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

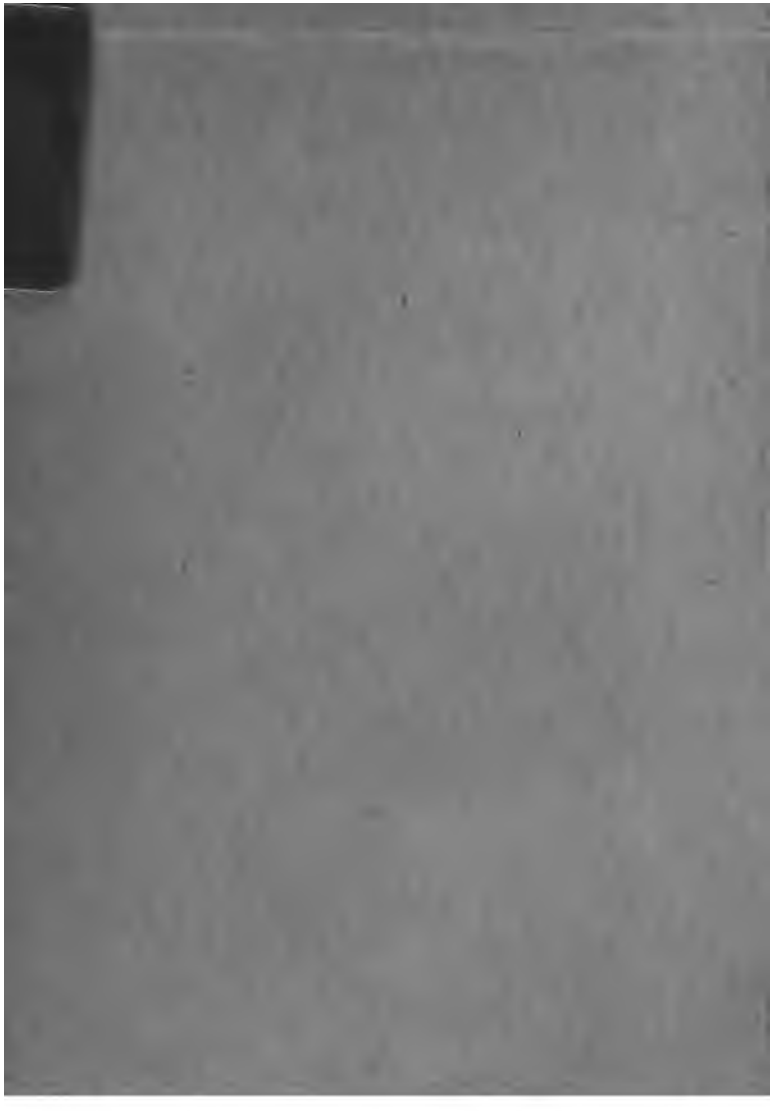
+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

3 3433 06637529 0



TELEGRAPH SECONDARY CELL INSTALLATIONS.

TELEGRAPH SECONDARY CELL INSTALLATIONS.

A

PRACTICAL WORK

ON THE

CHARGING AND MANAGEMENT

OF

ACCUMULATORS.

By

ARTHUR CROTCH,

Author of "Elementary Telegraphy and Telephony"; Silver Medalist and Honoursman in Telegraphy, and Honoursman in Telephony, City and Guilds of London Institute; sometime Lecturer in these subjects at the Municipal Technical Schools, Norwich.

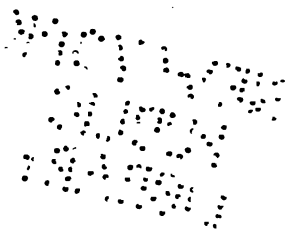
ONE HUNDRED ILLUSTRATIONS.

GUILBERT PITMAN,

85, Fleet Street, London, E.C.

1906.

THE NEW YORK
PUBLIC LIBRARY
ASTOR, LENOX AND
TILDEN FOUNDATIONS.
R 1906 L



[ENT. STA. HALL.]

(*All rights reserved.*)

PREFACE.

TO describe an installation of secondary cells a great deal more is required than merely to treat of the battery itself. Given the latter, the question of charging immediately arises. If a public supply of continuous current at a low pressure be available, direct charging is resorted to, but if the voltage be unsuitable a dynamo is necessary. An electric motor is then employed to drive the dynamo. In the case of an alternating supply, the motor will of course be single, two or three phase. All this machinery is quite outside the domain of telegraphy, from which standpoint the book is written. Hence, in order to add to its possible usefulness I have traversed, broadly and simply, the whole field of generators and motors—direct and alternating current —together with the accessories, voltmeters, cut-outs, etc., involved.

A. C.

ENGINEER-IN-CHIEF'S DEPARTMENT,
G.P.O., LONDON, E.C.

CONTENTS.

PAGE

CHAPTER I.—**Direct-Current Generators.**
Dynamo—Series and Shunt Machines—Ring Armature—Drum Armature—Commutator—Brushes—Diameter of Commutation—Lead—Two-pole Machines—Four-pole Machines 9

CHAPTER II.—**Direct-Current Motors.**
Principle of Motor—Counter E. M. F.—Direction of Rotation—Detailed description of Motor—Starting—Output—Efficiency... 29

CHAPTER III.—**Alternating-Current Machines.**
Alternator—Alternating-Current Circuit—Polyphase Currents—Alternating-Current Motors—Synchronous Motor—Rotating Magnetic Field—Polyphase Induction Motor—Starting—Single-phase Induction Motor 42

CHAPTER IV.—**Transformers and Motor Generators.**
Transformers—Ratio between Primary and Secondary E. M. F.'s—Alternating Currents in Primary—Transformers for Continuous Currents—Motor-Generator ... 66

CHAPTER V.—**Ammeters and Voltmeters.**
General description—Stanley D'Arsonval Instruments—Cell-testers—Weston Instruments—Recording Instruments—Electrolytic Meter 75

CHAPTER VI.—**Evolution of Secondary Cell.**
General Principles—Electrolysis 88

CHAPTER VII—**Secondary Cells—General.**
Forming—Pasting—Voltage—Specific Gravity—Hydrometer—Theory of Secondary Cell—Sulphating—Buckling—Capacity—Efficiency... 93

CHAPTER VIII.—**Some Types of Cell.** PAGE

Hart Cells—Construction of Plates—Hart T-type Cells—Non-corrosive Terminal—Hart S-type Cell—Chloride Cells—E. P. S. Cells 101

CHAPTER IX.—**Equipment of Battery and Instrument Rooms.**

Main and Local Batteries—Racks—Equalising of Load—Charging—Battery Room Cabinet—Rotary Switches—Bare Wire Resistances—Instrument Room Cabinet—Table Cases—Protective Resistances ... 118

CHAPTER X.—**Charging Arrangements.**

Means of Charging — Motor Generator — Dynamo Board — Electro-Magnetic Cut-out — Motor Board (direct-current)—Motor Board (single phase alternating) — Direct Charging — Diagram of Charging Circuit 141

CHAPTER XI.—**Practical Operations.**

Method of Setting up Cells—Mounting on Racks—First Run of Dynamo—Starting Motor—Dynamo failing to excite — Checking Connections — Initial Charging of Cells 157

CHAPTER XII.—**Care of Secondary Cells.**

Usage—Purity of materials—Introduction of impurities—Evaporation losses—Importance of using pure water—Systematic E. M. F. and Hydrometer tests of each Cell—Time to take—Abnormal behaviour of Individual Cells 166

CHAPTER XIII.—**Use of the Gas-Engine.**

Combustion — Explosion — Description of the Gas-Engine—Cycle of operations—Water cooling—Governing—Gas supply—Silencer—The Oil-Engine 171

TELEGRAPH SECONDARY CELL INSTALLATIONS.

CHAPTER I.

DIRECT-CURRENT GENERATORS.

FOR the generation of the powerful currents required for electric lighting and power purposes the primary battery—as represented by the Daniell, bichromate, or even the Groves cell—is obviously inadequate. An apparatus is demanded of greater output, and free from the laborious processes of recharging by the reassembling of fresh chemical agents. This apparatus is found in the "dynamo-electric machine." The latter term is a generic one, and covers the machinery entirely, whether used as a generator or a motor, employing direct or alternating currents. These are all based on the principle of magneto-electric induction or the relative movement of a magnetic field and a conductor.

In Fig. 1, *pqrs* is a single turn or coil of wire placed so as to be capable of revolution in the channel formed by the hollowed-out poles of a powerful horseshoe magnet—only one pole of which is

shown. The direction of the lines of force is indicated by the arrows *w w*. The dotted line, *x y*, represents the shaft carrying the coil, and this shaft has at its forward end two copper rings, insulated from each other and from the shaft. Pressing on these, so as to secure good contact, but not sufficiently hard to impede the turning of the coil, are two copper strips, or "brushes," A and B, which lead to the external

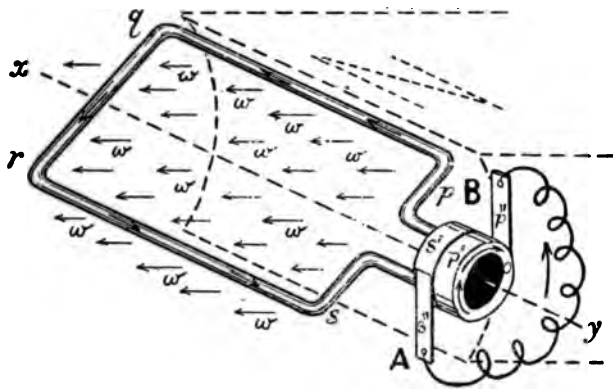


FIG. 1.

circuit. The end, *p*, is connected to the ring in contact with B, and end *s* to the ring touching A.

Now, with A and B joined externally, if the coil be turned sharply in a clock-wise direction, the upper portion *p q* will descend and "cut" the lines of force, and this cutting will induce a current in the direction *p q*. Whilst the upper limb is descending, the lower one, *r s*, is ascending and cutting the lines in an opposite sense, giving rise to a current in the direction *r* to *s*. But these two currents, although

reversed as regards the two limbs, are in the same direction as regards the complete coil, and a current, due to the action of both portions, leaves the ring *s'*, and traverses the external circuit in the direction A B.

Whilst this has been going on the coil will have turned through half a revolution, and the portion *r s* will now be uppermost and *p q* lowest. If the motion be continued for another half revolution, *r s* will

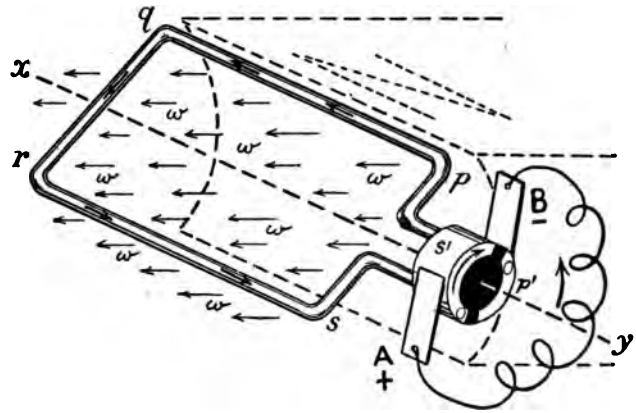


FIG. 2.

descend and *p q* ascend—that is, their motion will be reversed, and a current due to them both will traverse the coil in the direction *s r q p* and the external circuit B to A. Hence, if the coil be turned continuously, two currents will be set up per revolution, and these will be in opposite directions. In other words, an "alternating" current is set up, and the machine is an "alternator."

Instead, however, of using the two complete rings

for the collection of the current, we may adopt another device, shown in Fig. 2. This is a single ring, cut in halves so as to form two semi-circles, the ends *p* and *s* of the coil being connected one to each. When *p q* is descending and *r s* rising, as we first considered, a current flows through the coil in the direction *p q r s* and through the external circuit from A to B. At the next half revolution, when the current in the coil is in the direction *s r q p*, the segment *p'* has left B and is in contact with A; similarly, the segment *s'* has left A and is touching B. The current, therefore, although reversed in the coil, passes through the outer circuit from A to B, or in the same direction as before. The office, then, of the halved ring is to "rectify" or "commute" the alternating currents generated in the coil, and to deliver them to the external circuit in one direction only. For this reason it is termed the "commutator," and fitted thus our apparatus becomes a "dynamo," or a direct current generator. The two classes are generally spoken of as dynamos and alternators. We will now consider the former. A typical machine is illustrated in Fig. 3, details of which we shall consider later.

Dynamo.—In Figs. 1 and 2, if we regard *p q* only, the E.M.F. induced therein (giving rise to a current if the circuit be closed) will have a certain value, depending on the strength of the magnetic field, the length of *p q*, and the rate at which it cuts this field. Similarly with *r s*. But these two portions are in series with each other, and are cutting the lines at the same time. Hence the E.M.F. in *p q* is additive to that in *r s*. It follows therefore that the greater the

length of the conductor cutting the field at the same time the greater the induced E.M.F. If our coil, then, instead of consisting of a single turn, have many turns, its E.M.F. will be much increased. It will be seen that the back portion *q r* of the coil and the front portions parallel therewith simply pass *between*

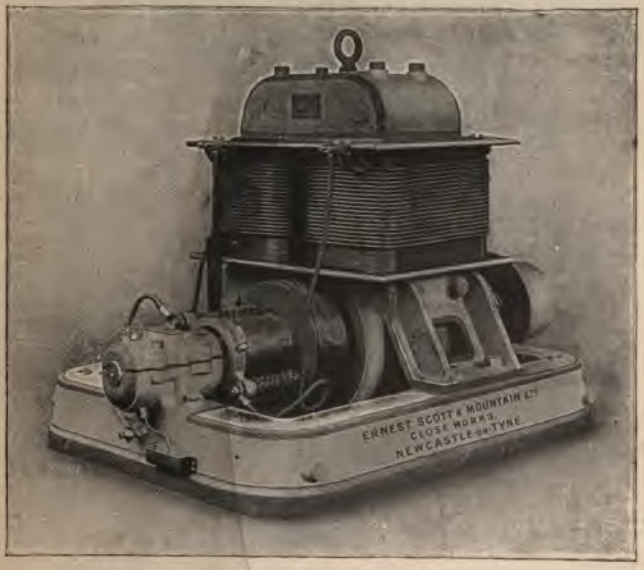


FIG. 3.—TWO-POLE DYNAMO.

the lines, and do not cut them. These parts are therefore idle, and do not contribute to the E.M.F. of the coil. Their resistance is, of course, added.

Now, when the coil approaches an upright position —one limb in the highest and the other in the lowest position—its movement, over a limited space, is

almost parallel with the lines of force. Instead of cutting the latter, the coil is slipping between them, and no E.M.F. is induced. As its revolution is continued it cuts an increasing number until, in passing the horizontal position, it cuts the greatest number possible. That is, if the coil is turned at a uniform rate, it cuts the maximum number of lines in a given

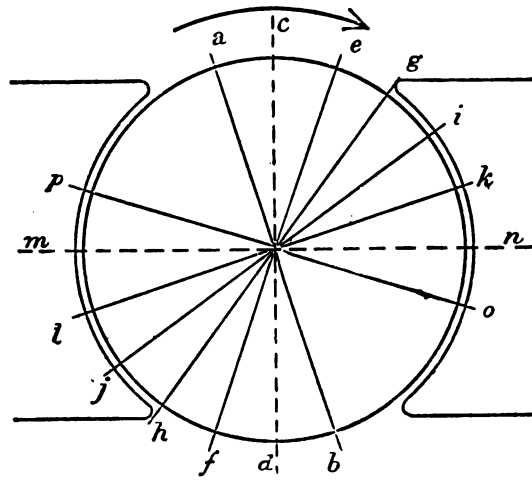


FIG. 4.

time when passing the horizontal position. This will easily be seen from Fig. 4. The circle indicates the journey of the coil, *c d* represents the upright, *m n* the horizontal, and the other lines show other intermediate positions of the coil. The series of lines, if continued round the circle, would divide it into twenty equal portions. If the coil occupies, say, one second of time in making a complete revolution, it will take

$\frac{1}{20}$ of a second in passing from position *g h* to that represented by *i j*, and so on. In other words, the coil occupies equal times in passing from any one position to the next. Now, in moving from *a b* to *c d* the movement of the coil is practically parallel with the lines, hence none are cut. Similarly, in passing from *c d* to *e f*. From *e f* to *g h*, however, the coil cuts a few lines; thence to *i j* a larger number, and in progressing to *k l* a much larger. In passing from *k l* to *n m* and from *n m* to *o p* it cuts the maximum number of lines. Each of these steps being covered in an equal length of time, the E.M.F. rises gradually from zero to its highest value. Continuing its journey from *o p* to *f e*, the coil passes through similar stages, but with decreased cutting, and the E.M.F. falls to zero. This is the result of a half revolution. In completing the full revolution the same effects occur, of gradual rise and fall of E.M.F., this time in a reverse direction, but by means of the commutator the reversal is prevented from extending to the outer circuit. In each revolution, then, there are two positions when the induced E.M.F. is at a minimum or nil, and two when it is at a maximum. Hence the continued turning of the coil sets up in the outer circuit, not a steady, continuous current, but a series of impulses, each of which rises gradually to its height and then gradually dies away.

If we place another complete coil at right angles to the first, then one will be in the position of maximum activity, whilst the other is inactive, and the impulses will succeed each other more quickly. In practice, therefore, a large number of coils is employed; the pulsations of current then follow each other so rapidly

as to form a practically continuous current. The increase in the number of coils involves a greater number of parts in the commutator: for four coils our ring must be cut to form four segments, and so on.

Let us now place a soft-iron "core" in the interior space of the coils. The lines of force of the iron will be added to those already existing, and the magnetic field will be enormously strengthened. The coils in turning now cut a much larger number of lines in the same time, and the E.M.F. is proportionately increased. This core, of cylindrical shape, is mounted on the shaft and carries the coils; the three members, with the commutator, constituting the "armature." In the early machines the iron was a solid mass, and a grave disadvantage ensued. In turning, the core itself cuts the field just as the coils do, and being a good conductor and of great cross-section, large currents are set up in it—these being reversed twice per revolution, as in the coils.. The core then is traversed by powerful, rapidly-alternating currents, which contribute nothing to the external circuit, but are confined to the iron alone. Hence they are utterly wasted, and in addition, they heat the armature to a dangerous degree. The heat increases the resistance of the conductors themselves and damages their insulation. The iron, therefore, is now not a solid mass, but is *laminated*, or built up of thin plates or laminæ. That is, the iron core is formed by stringing thin discs on the shaft, these discs being insulated from each other by layers of varnish or of thin paper. The iron is thus still continuous from pole to pole, or in the direction of the lines, but is not continuous in that of these wasteful "eddy" currents.

Series and Shunt Machines.—Up to the present we have considered the magnetic field as being provided by a permanent magnet. This method, however, gives comparatively feeble results, and is impracticable. Electro-magnets are therefore used. These, termed from their function the "field-magnets," are excited by means of current from the armature. In one arrangement the whole of the armature current is carried round the field-magnet coils before going to the external circuit, as illustrated in Fig. 5. The windings then consist of a few

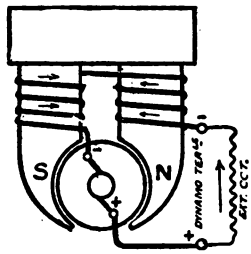


FIG. 5.—SERIES DYNAMO.

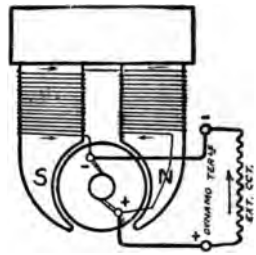


FIG. 6.—SHUNT DYNAMO.

turns of large, heavy conductor—and such a machine is a "series" dynamo. In another arrangement, indicated in Fig. 6, the field-magnets are wound with many turns of fine conductor, and have thus a comparatively high resistance. These are joined as a shunt upon the external circuit, so that the current from the armature divides, part being utilized to excite the field-magnets and part going through the outer circuit. This is a "shunt" dynamo. Sometimes the two methods are combined, giving a "compound-wound" machine.

We see now that the E.M.F. developed by a dynamo depends on (*a*) the length of conductor, or the number of turns employed in cutting the magnetic field; (*b*) on the rate at which the conductors cut the field, or on the speed of rotation; and (*c*) on the strength of the magnetic field. Having treated in this introductory manner, of the members of the direct-current generator, we will now consider them as in actual practice.

Ring Armature. — There are practically two classes—the ring or cylinder, and the drum. Th

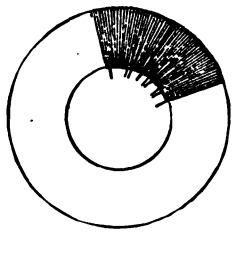


FIG. 7.

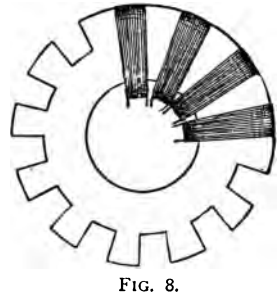


FIG. 8.

core of the former, instead of being built up of disc as we have considered, is formed of large, thin rings or washers, suitably supported on the shaft. These washers may have either plain exterior edges, or may have deep slots cut in the edges so as to leave projecting teeth—termed, from the inventor, Pacinotti teeth. In the first case, the coils are wound over the core so as to completely cover it, as in Fig. 7; and in the second they are confined to the slots or spaces between the teeth, as shown in Fig. 8. When the armature from back to front is comparatively short,

e., not a large number of washers used, we have a ring armature: with a large number of washers, forming a longer arrangement, the ring naturally becomes a cylinder. In both cases it will be seen that only the wire or conductors on the external circumference are usefully employed; for if any E.M.F. were induced in the inner winding of the ring, it must oppose

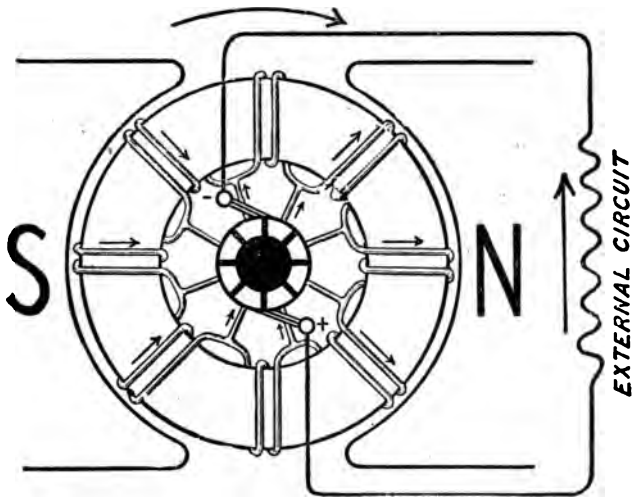


FIG. 9.—RING ARMATURE IN TWO-POLE FIELD.

the true E.M.F. in direction. The lines, however, from one pole divide and stream through the upper and lower portions of the ring, reuniting at the other pole—practically none passing through the interior. This inner wire, with that on the ends of the armature, is thus idle.

Fig. 9 illustrates the principle of the winding of a ring armature. Eight coils only are shown, and these

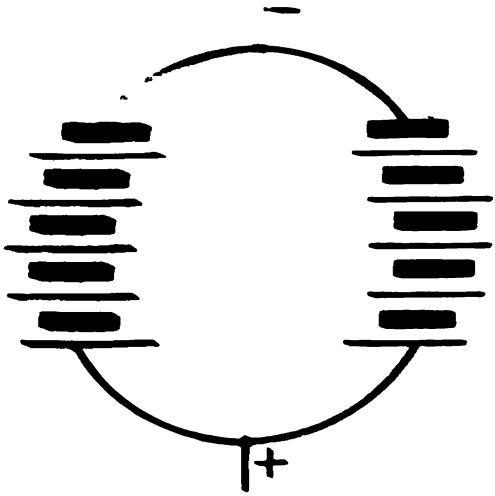


FIG. 10.

idle. The right-hand middle coil is undergoing maximum inductive influence—that is, it is cut the lines at right angles ; whilst the other two o right are in positions of equal medium activity, ar three are tending to send current in the same direc On the left the middle coil is in the positio maximum, and the other two in medium acti

These three are urging current in the opposite direction to those on the right hand. But the metallic strips, or "brushes," are pressing on the points where the reversal occurs, so that the state of affairs may be exactly represented by two equal sets of batteries placed in parallel, as in Fig. 10. The total E.M.F. is thus that of *one side* only, but the resistance is one quarter of the whole length of the coils. As the armature revolves, all the coils change places in succession, so that the figure practically represents the constant electric condition of the machine.

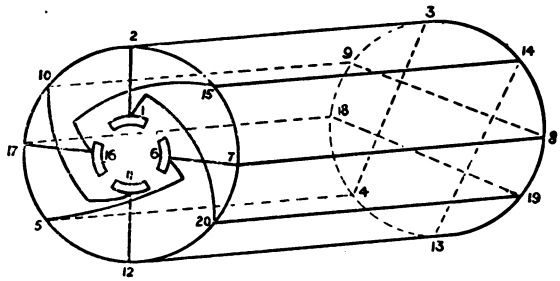


FIG. 11.

Assuming the armature to be rotated in a simple two-pole field, as in Fig. 9, and in the direction indicated, it will easily be seen that in the outer portions of the conductors on the right, the induced currents will flow from front to back, and in those on the left from back to front. The upper brush thus becomes the negative, and the lower brush the positive pole of the armature.

Drum Armature.—The core plates of this may be simple discs, with a hole for the shaft; or this latter hole may be so much enlarged that the discs

really becomes rings or washers as before. They ar
then attached to the shaft by means similar to thos
used in the ring armature. The circumference of th
discs may be left plain and covered with the wind
ings, or it may be slotted and the conductors lai

FIG. 12.

therein. The essential difference between the ri
and the drum arrangement, however, is in the windi
In the latter the conductors are entirely confined t
the exterior, there being no inner idle wire. Th

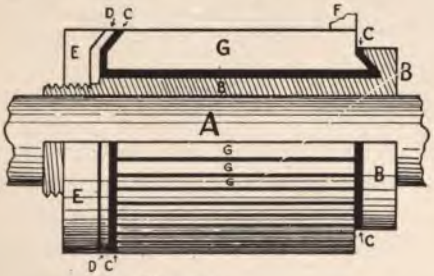


FIG. 13.

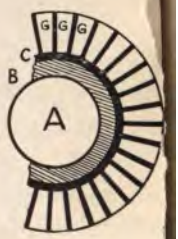


FIG. 14.

on the ends is, of course, inactive as before. Fig. 1
shows the principle of the winding, and Fig. 1
illustrates a complete armature of the slotted type
together with the commutator.

Commutator.—This consists of a number of hard-drawn copper bars or segments insulated from each other and from the shaft by thin plates of mica, the whole being mounted on a sleeve of gun-metal which, in its turn, is secured on the shaft. Fig. 13 is partly a side view and partly a side section of a commutator, and Fig. 14 is a portion of an end section. G G are the copper bars, each being shaped as shown, and separated from its neighbours and from the sleeve, B, by the insulator, C; D is a washer, and E a clamping ring which keeps all the bars in position; F is an extension, or lug, to which the junctions of the coils are connected.

Brushes.—Instead of the simple strips of Figs. 1 and 2, these are built up of smaller thin strips, sweated together at one end; or of copper wires similarly treated. Another form consists of fine wire, plaited or woven together; this is then put under pressure and covered with copper gauze. The end aimed at is to secure a comparatively soft mass to bear on the commutator, so as to make good contact without undue wear. Carbon brushes are now very largely used. These consist of small carbon blocks, mounted in suitable carrying pieces or brush-holders.

Whether of copper or of carbon, several brushes are combined in parallel to form one set—so as to afford good collecting surface. The brush-holders are mounted on a "rocker," which allows the brush system to be shifted to any position on the commutator.

Diameter of Commutation — Lead. — In Figs. 9 and 10 we assumed the lines of the field to be running horizontally. On this assumption, the two

halves of the ring whose E.M.F.'s are acting i parallel are on either side of a vertical diamete Now the brushes, obviously, must make contact wit the commutator in this vertical line, so as to pick u the positive ends of the two halves on one, and th two negative ends on the other brush. This line i therefore termed the "diameter of commutation, and is always at right angles to the direction of th field.

But in addition to the field proper, *i.e.*, that due the field-magnets, another field is set up by th current flowing through the armature, and this wi be in a vertical direction. The direction of th resultant field will, therefore, be somewhere betwee the two. The effects of the field-magnets, howeve are much more powerful than those of the current i the armature—hence the effect of the latter is simp to distort or twist the field proper in the direction rotation. The diameter of commutation, as we ha seen, is at right angles to the actual direction of t field, and as the points of contact of the brushes mu be along this diameter, the brushes have to be shift forward, or given a "lead" of the same amount as th displacement of the field. It is the function of th rocker to allow of this adjustment of the brushe to the proper points of contact on the commutat surface.

Two-pole Machines.—Figs. 3 and 15 are e amples of the type of machine which we have bee considering, viz., that in which the field is a simpl one, between a single pair of poles. Fig. 3 illustrate a dynamo constructed by Messrs. Scott and Moun tain, of Newcastle. The field-magnet, of horsesho

shape, is placed yoke uppermost, so that the armature is mounted on the base of the machine. This is termed, from the position of the armature, the under-type. The centre of rotation being low, this form is mechanically good, and tends to great steadiness in running. It has a drum armature, the conductors being carried in slots; and carbon brushes, the rocker-handle of which is shown just above and in

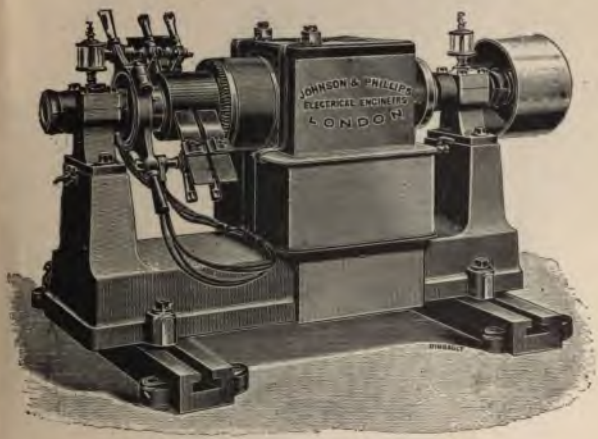


FIG. 15.—TWO-POLE DYNAMO.

front of the commutator. The field-magnets are shunt or series wound, according to the uses to which the machine is to be put.

Fig. 15 illustrates a type of two-pole dynamo, constructed by Messrs. Johnson and Phillips. In this the field-magnet is inverted, standing on its yoke. The mounting of the armature is thus raised considerably, and constitutes the over-type. The rocker, with its

handles above and below, and the copper brushes, are plainly seen in the figure.

Four-pole Machines. — Besides the preceding two-pole type, machines having two pairs of poles (four-pole), three pairs (six-pole), and more (multipolar), are employed, for various reasons. We shall

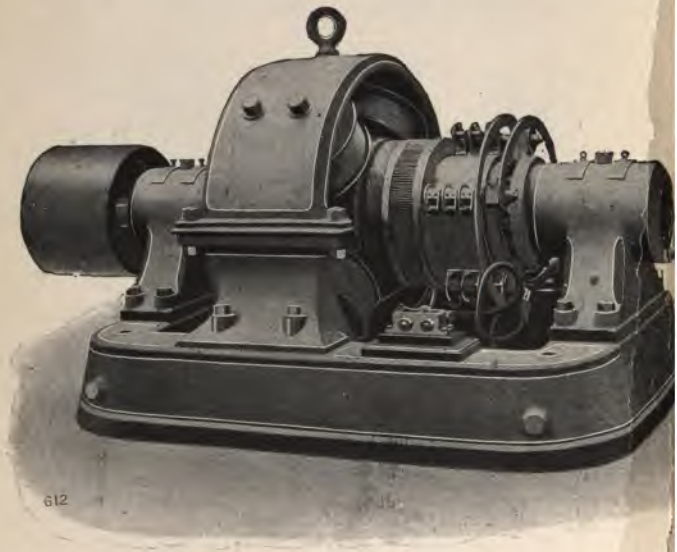


FIG. 16.—FOUR-POLE DYNAMO.

only consider a four-pole one, as this will illustrate the principle of them all.

Fig. 16 shows such a machine as manufactured by Messrs. Scott and Mountain. Instead of a horseshoe magnet, we have a ring with four inner projections *bolted* to it. These carry the field-magnet coils and

form the poles, the supporting ring acting as a common yoke. The armature, in this particular dynamo, is a drum, slotted to receive the conductors. In a two-pole field the current is reversed twice in each revolution of the armature. With a four-pole one it is reversed four times per revolution. We have also

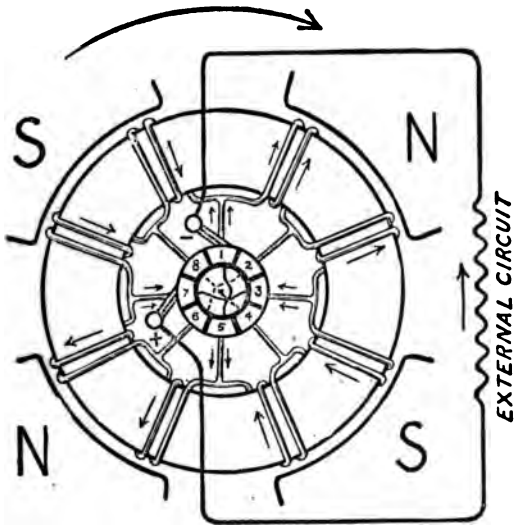


FIG. 17.—RING ARMATURE IN FOUR-POLE FIELD.

two diameters of commutation, and therefore two pairs of brushes. These are joined in parallel—positive to positive and negative to negative. The brushes are of carbon, as can be seen from the illustration. Instead of using two pairs, however, diametrically opposite segments of the commutator may be connected together, when a single pair of

CHAPTER II.

DIRECT-CURRENT MOTORS.

Principle of Motor.—When a conductor cuts a magnetic field, as we have seen, a current is set up in it. In order to produce the necessary motion, mechanical energy has to be applied. If, on the other hand, we cause a current of sufficient strength to pass through a conductor which is stationary in a suitable position in a magnetic field, the conductor experiences mechanical movement. A simple case of this is seen with a magnetic needle placed parallel with a wire. When a current is passed through the latter, the needle is deflected, and tends to set itself at right angles to the wire. The direction of the movement is such that the lines of force of the needle tend to approach parallelism with those of the wire.

Taking the case of the simple coil of Fig. 2, instead of causing it to revolve and thus giving us current, we will assume it to be in the position shown in Fig. 18, and that it is supplied with current from a battery. The direction of this current in the external circuit is the same as in Fig. 2. It flows from the battery to the upper brush (marked B in Fig. 2), enters the segment p of the commutator, passes through the coil in the direction $p\ q\ r\ s$, and leaves by segment s'. Considering the interior of the coil, the field set up may be regarded as represented by

the lines *n n s s*, with the arrow-heads at their upp extremities. The direction of the field, due to t poles of the permanent magnet, is horizontal, and indicated by the dotted lines, with the arrow-heads their left-hand extremities. Now, the field due the armature tends to set itself parallel with that the permanent magnets; or, in other words, the po *n n n* of the coil is repelled by the N pole of th magnet, and attracted by the S pole. Similar, bu

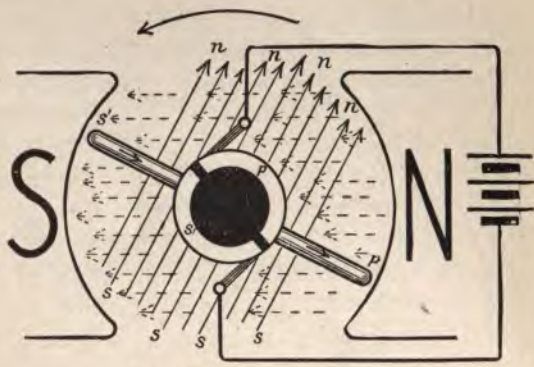


FIG. 18.—PRINCIPLE OF MOTOR.

opposite, attraction and repulsion take place wi *s s s*, and the coil turns in the direction indicated b the arrow at the top. When the first half-revolutio is completed, the current through the coil is reverse by the action of the commutator. The effect of th reversal is to keep the *n* pole of the coil uppermos and the armature is thus continuously rotated. Th direction of rotation is the reverse to that in which would have to be turned as a generator to set u

irrents in the same direction in the external circuit, id the brushes are set in the opposite direction to ose in Fig. 2.

Broadly speaking, then, the same machine will rve either as a motor or as a dynamo or generator. we apply mechanical energy to actuate it, we get ectrical energy given out. If we supply it with ectrical energy, it gives us mechanical energy in turn. Therefore, in having described the dynamo, e have also described the motor. Practical machines, course, are not built to be thus reversible, but eoretically they are capable of performing either nction.

Counter E.M.F.—It is easily seen that when a otor is running its armature conductors are cutting e lines of force of the field just as in a generator. his cutting naturally sets up a certain E.M.F. The otion, however, which causes the cutting is itself set) by the prime current; hence this E.M.F., being an fect, must naturally be less than the originating use, which is the E.M.F. applied to the terminals of e motor. Further, by an examination of Figs. 9 id 18, it is evident that this secondary E.M.F. is in e opposite direction to the prime E.M.F. from hich it arises. It is therefore termed the "opposing," e "back," or "counter" E.M.F. of the motor. The tter, indeed, is driven by a current due to the fference between the originating and the counter .M.F.'s.

This is a very valuable property of the electric otor. The greater the speed at which it runs, the eater the counter E.M.F. Hence when the machine running "light"—*i.e.*, doing no useful work—it runs

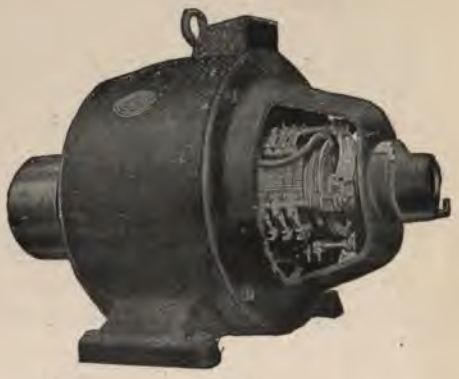


FIG. 19.

FIG. 20.

at its highest speed. The back E.M.F. then reaches a maximum, and the actual current $\frac{E-e}{R}$ (where E represents the applied E.M.F., e the counter E.M.F., and R the resistance) passing through the armature is reduced to a minimum. When the load is thrown on, the speed is immediately slowed down. The opposing E.M.F. is thus lowered, and a larger current flows, which exerts a greater pull.

Direction of Rotation.—Motors generally are either shunt or series wound. In the latter case, if the machine is supplied with current in the same direction as it would furnish as a generator, the armature revolves in the opposite direction. When a shunt-wound machine is so supplied it runs in the same direction as it would be driven as a dynamo, the current being reversed in the field-magnets. To reverse the direction of rotation of a shunt or series motor the current must be reversed in either the armature or the field-magnets, but not in both.

Detailed Description of Motor.—The following nine figures illustrate a "Witton" 4-pole motor and its various parts, as manufactured by the General Electric Company. Figs. 19 and 20 are two forms of the complete machine. A cast-iron ring or cylinder, into which four pole-pieces of mild steel are cast, constitutes the frame of the motor. This is shown in Fig. 21. On these pole-pieces are placed the field-coils, of circular shape (Fig. 26), and on the inner ends are fitted wider laminated extensions or shoes, which embrace the armature. The latter is of the drum type, and is built up of charcoal iron plates, each plate being insulated from its neighbours. These are slotted to receive the coils, a single one of

FIG. 21.

FIG. 22.

FIG 23.

FIG. 24.

FIG. 25.

FIG. 26.

FIG. 27.

FIG. 21.

FIG. 22.

FIG 23.

FIG. 24.

FIG. 25.

FIG. 26.

FIG. 27.

which is illustrated in Fig. 27. The com
ture, with commutator and shaft, is seen
and an enlarged view of the commutator
which shows clearly the connections to the

Being a four-pole machine, either the co
bars must be cross-connected, as in Fig.
pairs of brushes must be used. The latte
is adopted. The four sets of carbon brushes
in holders of gun-metal and carried by
are shown in Fig. 25, as are also the
conductors.

The armature bearings are mounted in
shields (Fig. 22), which are bolted to the
Each of these shields consists of a circular
a broad bridge-piece which carries the bea
either side of this bridge-piece is a kind
fitted with a hinge and shaped so as to cov
shield. Each door has two apertures cut in
19 is known as the "open protected" type
this the shields are minus the doors. Hence
the bridge-bearing pieces serve as protective
covering, the open sides allow of easy access
inspection of the commutator, etc. Fig. 2
"enclosed ventilated" type. The shields in
are fitted with the doors, and the apertures
are covered with wire mesh. Two other ty
constructed—the semi-enclosed, having the ap
in the doors quite open, and the totally-enclo
which the apertures are provided with solid
so as to entirely cover in the interior parts.

Starting.—It follows, in consequence
counter E.M.F., that the working current o
is never that $(\frac{E}{R})$ which would result from

on by its resistance of the E.M.F. applied, but a lower value $(\frac{E-e}{R})$. In starting, however, if we nly apply the full E.M.F. at our disposal, the being at rest, and the counter E.M.F. therefore he resulting current will be very much greater the conductors of the armature were designed to Hence great damage or complete "burning-

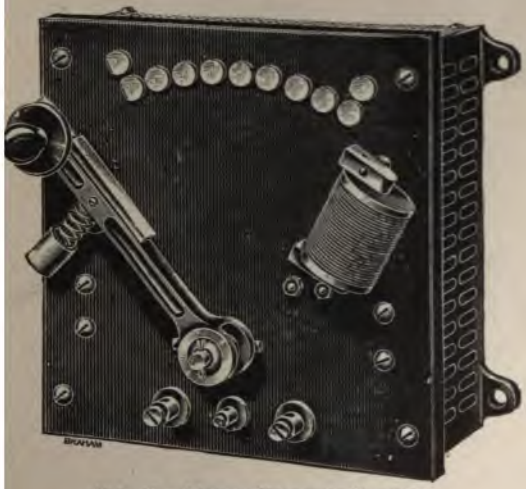


FIG. 28.—MOTOR STARTING SWITCH.

would result. A graduated resistance is there-nserted, so that the initial current shall be small. he motor speeds up, and the counter E.M.F. ops, this resistance is gradually reduced and y cut out. With a series motor this starting ance is in the main circuit of both field-magnet armature; but with a shunt-wound motor it is ed to the armature circuit, the field-magnet—

of comparatively high resistance—being co
directly across the mains. A starting switch
purpose is shown in Fig. 28, and its conn
together with the motor, are given in Fig. 2

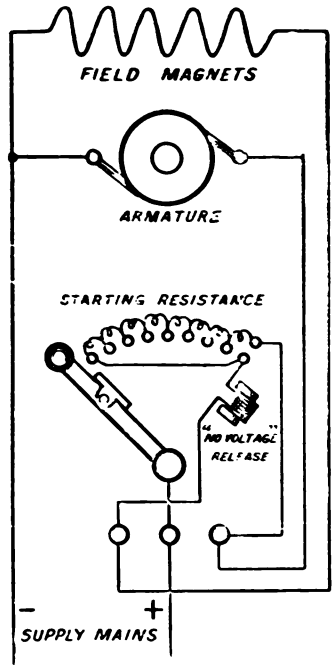


FIG. 29.

negative main is brought (through a suitable
to one side of the armature and to one side
field-magnet coils. The other sides of these
nected to the two ends of the starting res
which is cut up into sections by the series c

On the field-magnet side of this resistance a small electro-magnet is placed in circuit. The positive main is brought (also through a switch, not shown) to the lever. When the latter is moved over to the first contact, the positive main is connected through the electro-magnet to the field-magnet coils which are thus thrown directly across the mains. A path is also opened through the whole resistance to the armature, and the motor starts. As the speed increases and the counter E.M.F. develops, the lever is moved, step by step, to the right. This cuts out sections of the resistance from the armature circuit, and throws them into that of the field-magnet. When the last stop is reached, the starting resistance is short-circuited, and the full E.M.F. of the supply is connected to both armature and field-magnet. The lever carries a small soft-iron armature, and when the armer reaches its right-hand limit this armature comes in contact with the poles of the electro-magnet, through which the field-current is flowing. The lever is thus held fast in this position against the pull of a spring which tends to bring it to the left. This is the "no-voltage release," and its office is as follows: Suppose the main current to be cut off—say at the central supply station—for a short time and then suddenly restored. If the interval be long enough to allow the motor to come to rest, the restoring of the current will be liable to burn out the armature. With this arrangement, however, as soon as the current fails, the small electro-magnet ceases to be energized, and allows the lever to fly back to the left. The machine can then be re-started only by the operation of the lever.

Output.—We measure the energy of a steam-engine in horse-power, and the amount which it is capable of giving out is termed its *output*. Similarly with a dynamo, one of a certain size and proportions is capable of giving a certain output. This, of course, is electrical energy, and it is measured in *watts*, these being the product of the E.M.F. and current—1 volt × 1 ampere = 1 watt. As this unit is somewhat small, the kilo-watt (1,000 watts) is frequently employed. A dynamo giving an E.M.F. of 100 volts and capable of delivering 1,000 amperes to the external circuit has thus an output of 100 × 1,000 = 100,000 watts or 100 kilo-watts. Such a dynamo is spoken of as a "100-unit" machine.

Efficiency.—A steam-engine is a machine for the conversion of the energy of heat to that of mechanical force. We supply the boiler with coal which, under suitable conditions, combines with the oxygen of the air, and liberates vast stores of heat. The energy of this heat, through the intermediation of the boiler and engine, reappears at the pulley of the latter as mechanical energy, available for driving machinery or performing other work. Similarly, the dynamo or generator is an apparatus for converting mechanical into electrical energy. An electric motor, on the other hand, performs the converse operation of changing electrical into mechanical energy. Now, whenever we change energy from one form to another there is always a loss in the process—the loss in conversion. The greater this loss the less efficient the machine. The efficiency, then, of a machine is the relation between the energy given out by and that supplied to it. Considering the steam-eng

nd boiler as one machine, it is a singularly inefficient iece of apparatus. In the best makes the efficiency s only about 15 per cent That is, if we put a nundred units of heat-energy into the furnace of the boiler, we get only fifteen units of mechanical energy from the engine. From a theoretical point of view, then, this is a very inefficient machine; but, practically, this is not felt, since fuel is cheap.

The efficiency of a dynamo is the ratio between the electrical energy given out and the mechanical energy used to drive it. The relationship between the electrical and mechanical units is such that 746 watts are the equivalent of one horse-power, or 746 watts = one electrical H.P. Thus, if the 100-unit machine, previously mentioned, takes 167·5 H.P. to drive it, the efficiency is

$$\frac{\text{Output ...}}{\text{Intake ...}} = \frac{\frac{100{,}000}{746}}{167{\cdot}5} = \frac{134}{167{\cdot}5} = {\cdot}8 \text{ or } 80 \text{ per cent.}$$

In contradistinction to the above, which is the ommercial efficiency, we also speak of the electrical ficiency of the dynamo. This is the ratio between ectric energy given out and total electric energy eveloped. The former is, of course, the energy ven to the external circuit; the latter is the energy ven out, plus that employed in energizing the field-agnets.

The efficiency of a motor is the ratio between the echanical energy given out and the electrical energy sed to drive it.

CHAPTER III.

ALTERNATING-CURRENT MACHINES.

The principle of the alternating-current generator is given in Fig. 1, where the two collecting-rings allow the alternations set up in the armature to pass, uncommuted, to the external circuit. The design of the alternator is generally very different to that of the direct-current dynamos; we will consider a well-known type.

Alternator. — Fig. 30 illustrates an alternator constructed by Messrs. Johnson and Phillips. In this the armature is stationary, and the field-magnet rotates. The outer iron frame carries inside it the armature core, consisting of a broad inner ring of soft iron or steel. This ring is not a solid mass, but is built up of a large number of thin rings, magnetically insulated from each other. Near the inner edge of this laminated ring are the slots which carry the winding. Fig. 31 is a side view of a portion of the armature and field. This shows the outer frame and the inner core pierced by the (empty) slots. Fig. 32 illustrates the same portion of the core laid flat, or as seen from the inside of the ring. The coils, sixteen in number, have sixteen turns each, eight turns being placed in each slot. The inner end, y, of the first coil, is connected to the inner end of the second; the outer end, x, of the latter to the o of the third, and so on.

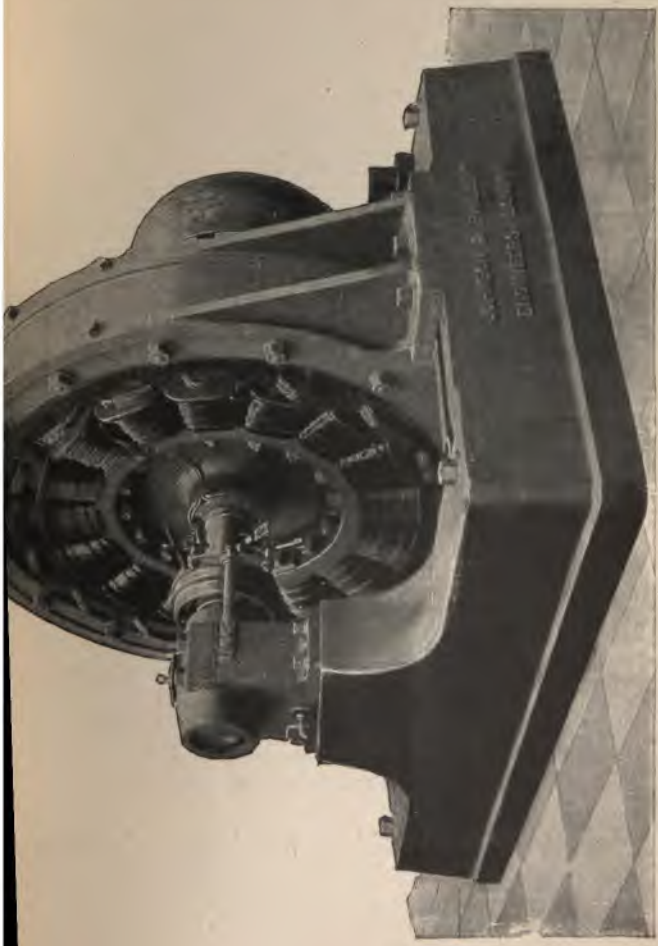
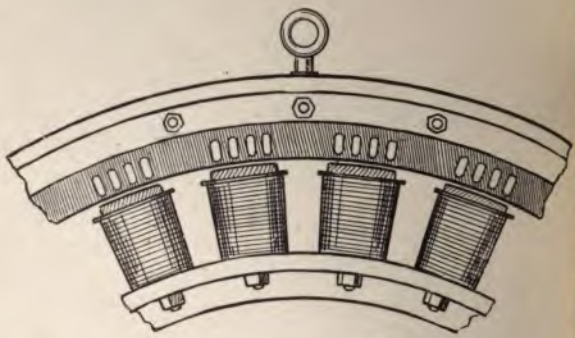
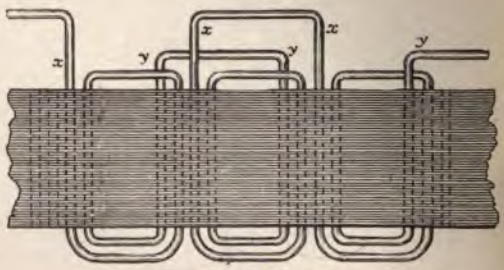


FIG. 30.—ALTERNATOR: ROTATING FIELD TYPE.

The rotating portion consists of a central iron hu
firmly secured to the shaft, and to the outer circu
ference of this are bolted the cores of the sixte
electro-magnets forming the field. On the ends





FIGS. 31 AND 32.

these, pole-pieces or shoes are fixed. The magne
are wound with insulated copper strip so as to pr
duce alternate N. and S. poles—the iron hub servi
as a common yoke. The ends of the field-windi
are brought to two insulated rings mounted on t

ft, and by brushes pressing on these the exciting rent from a separate direct-current dynamo is ied to the field-coils.

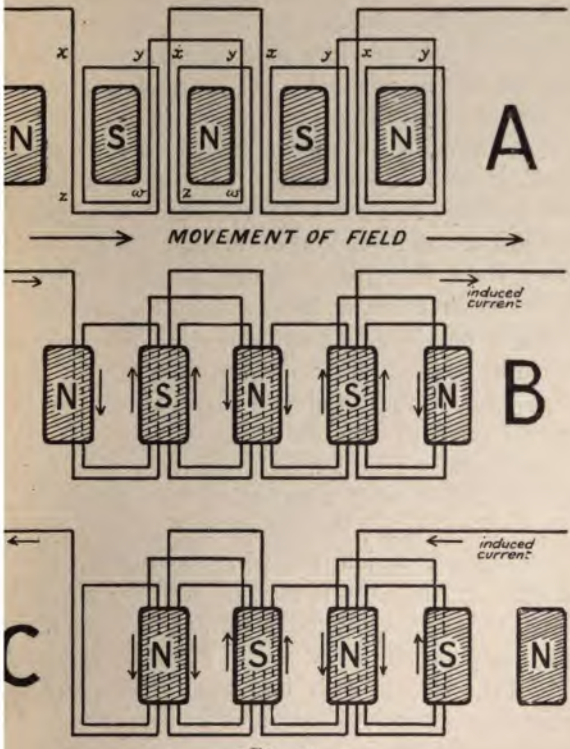


FIG 33.

he three stages A, B, and C of Fig. 33 show in ail the setting-up of the E.M.F. by the movement he field-magnets. Four coils are indicated, lying as in Fig. 32, and over these the magnet-poles

sweep, successively revealing and concealing the coils from our view. Each group of four slots carries half the active winding of two succeeding coils; that is, each coil occupies two slots of two adjacent groups. When the poles, with regard to the coils, are passing the idle or zero position shown at A, no E.M.F. is being set up, as the poles are immediately over the interior spaces of the coils. As the field moves to the right the lines of force projected from the poles cut the conductors in the slots. The position of maximum cutting is shown at B, where the poles are exactly over the groups of slots. An N pole, in passing the conductors, induces currents therein in a downward direction, as indicated by the arrows. An S pole, in passing, sets up currents which flow in an upward direction. By connecting up the coils in the manner shown, these induced currents all flow in the same direction as regards the entire armature. The result, therefore, of the movement from A to the next zero position is that a pulsation of current is sent through the circuit (the latter being closed) in a certain direction, which we will term positive. In moving from this second zero position to a third the magnet-poles pass the coils again as at C. This time each group of slots has an N pole passing over it where in position B it had an S, and *vice versa*. Hence this second pulsation is in the reverse direction to the first, or is a negative one. In moving forward another step a third current, similar in direction to the first, is urged through the circuit.

This movement of two steps, resulting in a positive and a negative pulsation, is termed a "cycle"; as there are sixteen poles on the field, and six

nature coils, each revolution will set up sixteen pulses, or eight complete cycles. The number of cles set up per second is the "frequency" or eriodicity" of the machine, and is denoted by the m ~. This particular alternator is designed to n at 500 revolutions per minute, or $8\frac{1}{3}$ per second. ence its frequency is 66 ~ per second.

The impulses of E.M.F.—giving rise to impulses of rrent if the circuit be closed—rise gradually to eir maximum value and gradually die away, as we v in the case of the direct-current dynamo. They

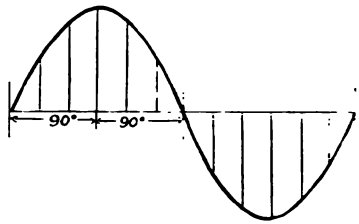


FIG. 34.

graphically shown in Fig. 34, the horizontal line resenting the time occupied in making the cycle, l the vertical lines representing the height or value the induced E.M.F. This period is usually con- ered as an angle of 360°. Thus, starting from o, the E.M.F. gradually rises to a positive maxi- m at 90°, falls to zero at 180°, rises to a negative ximum at 270°, to fall to zero at 360°.

Alternating-current Circuit.—In any circuit versed by a steady continuous current, the relation ween the E.M.F., resistance, and current, is ex- ssed by Ohm's law, $C = \frac{E}{R}$. When, however, the

current is started, stopped, reversed, or varied in strength, this simple expression does not hold good. If there be considerable capacity, the initial flow on closing circuit may be larger than its steady value. Again, if large self-induction or inductance be present, the initial current will be much less than its steady strength. The effects of self-induction and capacity, being felt only at starting, stopping, and varying the current, have not to be considered in continuous current working. With alternate currents, however, no sooner is the flow established in one direction than it is reversed—in fact, the steady state is never attained, but a regular series of startings and stoppings is set up. The capacity and inductance of the circuit are thus of the greatest importance, whilst the resistance may be comparatively unimportant.

Ohm's law states that the current varies inversely as the resistance. If we substitute "obstruction" for resistance, so as to include anything that opposes the flow of current, the relationship expressed by the law still holds good. With continuous working, the obstruction is simple resistance; with alternate currents the obstruction is "impedance," which is a complex quantity, depending on resistance and "reactance." Reactance, in its turn, depends on the inductance of the circuit and the frequency. Inductance is at a minimum when the circuit consists of straight conductors; is greater when coils are included; and is at a maximum when these coils contain iron. It is measured in *henries*. Further, a magnetic field must cut a conductor, or *vice versa*, at varying rates: quicker the movement the greater the E.M.F.

d. Hence, the higher the periodicity, the greater reactance.

ıe relationship between these quantities may be ın by a right-angled triangle, where the hypo- se represents the impedance and the other two ; the resistance and reactance respectively. ce—

ıpedance.² = Resistance² − Reactance²
= (Resistance² − Frequency × Inductance²

r,

dance = √(Resistance² − Frequency × Inductance²).

nce the current never attains a fixed value, but is ys rising and falling, we cannot speak of its ıdy strength." However, the pulsations follow other so quickly that for most practical pur- s the variations are imperceptible. For instance, ıspection we cannot tell whether an incandescent ı is fed by continuous or alternating current, the in both cases being perfectly steady. This gives ready means of comparison between the two :ms. If the lamp, to glow properly, requires a nuous current of half an ampere, then the alter- ıg current which will produce the same effect is to be of the same strength. This, of course, res the varying values through which the current es, and is spoken of as the "virtual" current, or 'virtual amperes." Similarly, the alternating .F. is measured in "virtual volts." It should orne in mind, however, that the maximum values above these virtual heights. The insulation of a luctor, for instance, must be designed to with- d the maximum pressure reached—not the ıal value.

The inductance of a glow lamp is practic negligeable. In a circuit, therefore, consisting wh of lamps, the current is "in phase" with the E.M —that is, they rise, fall, and pass through their v ing values together. With an electro-magnet, h ever, the inductance chokes back the current so t its rise and fall take place behind the rise and fa the E.M.F. The former is then out of phase with latter, and lags behind it. The result is that befo pulsation of current in one direction has been c pleted, the commencement of a succeeding pulsa of E.M.F. in the reverse direction opposes it. Thi of great importance, as it reduces the "power fact of the circuit.

The effect of capacity is exactly opposite. I sufficiently large condenser be inserted, the cur may "lead" or be in advance of the E.M.F. Adv tage is taken of this to introduce sufficient capa to neutralise the effects of self-induction and to b the current into phase. The amount of both lag lead is measured by reference to the period of 3 and is spoken of as the angle of lag or lead, as case may be.

Polyphase Currents.—The alternating cur just described is of "single phase." The fiel usefulness for power purposes of the alterna current, however, has been enormously extended the employment of "polyphase" or "multipha currents—generally confined to two and three-ph

In Fig. 35 are two similar alternators rigidly nected together by being mounted on one s their armatures being connected to two dist circuits. The field of the second is so placed

regard to the first that whilst the poles of the one are passing the coils, as at B or C in Fig. 33, the poles of the other are between the coils as at A in the same figure. The crest of each E.M.F. wave of one machine therefore coincides with the time of reversal, or zero position, of the other. The two circuits form

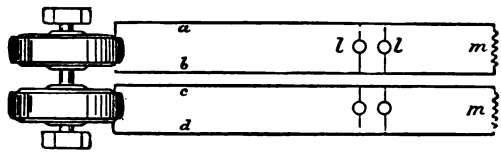


FIG. 35.—PRINCIPLE OF TWO-PHASE SYSTEM.

two separate single-phase systems, both of which are used to light the lamps *l*, *l* as usual. Between the two E.M.F.'s thus set up, however, there is a difference of phase of 90°, or they are in quadrature with each other. If we have a motor *m* with two windings, one

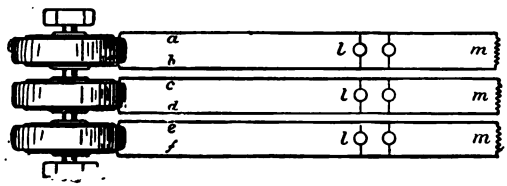


FIG. 36.—PRINCIPLE OF THREE-PHASE SYSTEM.

in each phase, the currents due to both will pass through it. This is a two-phase system.

Further, in Fig. 36 we have three similar alternators coupled together, with their armatures connected to three distinct single-phase circuits. The fields are so set that there is a difference of phase of 120°, or

one-third of a period, between each circuit and its neighbour. A machine with three windings, as above, will be traversed by the currents in all three phases. This is a three-phase system.

In practice, the two or three alternators are not used, but one machine carries two or three systems of coils. Reverting to Figs. 31 and 32, it will be seen how this is effected. Between any one group of slots and the next is a vacant space. If we insert a second group of slots in these spaces and provide them with a separate winding, we shall transform this single-

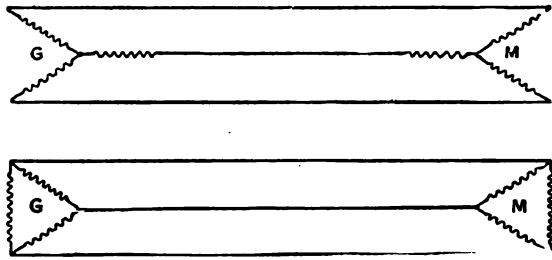


FIG. 37.—THREE-PHASE. STAR AND MESH WINDINGS.

phase alternator into a two-phase one. Or, altering the proportions of our machine somewhat, we may insert two new groups of slots in each vacant space and furnish these with two additional windings. We shall then have a three-phase alternator. The only practical difference, then, between a single, two, or three-phase machine is in the winding.

A two-phase motor (*m*, Fig. 35) has two sets of coils (like the generator), one being in circuit with each phase. A three-phase motor has three sets similarly placed. Thus the former requires four and

the latter six conductors between generator and motor. Generally, however, for both two and three-phase, only three mains are employed. In the first case the two conductors, *b* and *c* of Fig. 35, are replaced by a single one, which is connected to both coils of the motor and of the generator. Each main in turn then serves as the return for the others. For three-phase work the pairs of conductors, *b c* and *d e*, are replaced by single ones, and two plans of connecting up are in use, the star and the mesh or delta, shown in Fig. 37, G being the generator and M the motor. The former consists in connecting together one end of each of the three coils and taking the three free ends to the lines. In the mesh arrangement the coils are joined in series, and the three junctions connected to the lines.

Fig. 38 is a three-phase alternator of the revolving field type, manufactured by the Lancashire Dynamo and Motor Company. The exciter is carried on the same shaft. The principle of the winding, which is star-connected, is given in Fig. 44.

Fig. 39 shows graphically the rise and fall of E.M.F. in a two and in a three-phase system, as Fig. 34 shows it in a single-phase. The distance between the vertical lines in all three cases is 30°. Taking the crests of the E.M.F. waves, we see that in the two-phase system a positive impulse in phase *a* is followed, 90° later, by a positive one in *b*; 90° later a negative impulse is set up in *a*, followed by a negative in *b*. With the three-phase system there is a positive impulse in *a*, then a negative in *c*, followed by a positive in *b*, at intervals of 60°. These are shown by the signs at the foot of the diagram.

or couple it to machinery so as to give it work to d it will continue to run at the same speed—the spee of the generator. If it be overloaded it will not ru slower, but will stop altogether. Further, it cannot start of itself, but must be run up to the proper speed by external means before the driving currents are allowed to flow. This machine is then a "synchronous" motor; that is, it runs in exact synchronism with the pulsations of the driving current. Having the same number of poles as the generator, it runs at the same speed as the latter. If it had half or twice the number, it would run at twice or half the speed. The periodicity of the supply being fixed, the speed of a given motor is thus pre-determined and cannot be varied. This may be an advantage, but is generally the reverse; the greatest disadvantage, however, is its inability to start itself.

A much more flexible and practical machine is the "induction" motor, actuated by single or polyphase currents. Since, however, the latter are the key to the apparatus, and the single-phase a kind of adaptation, we will consider the polyphase induction motor first; but as a preliminary we must refer to an illustrative experiment.

Rotating Magnetic Field.—Reverting to the four-pole dynamo of Figs. 16 and 17—the field-magnet, of course, is stationary, and the armature rotates. But imagine the latter to be fixed—immovable—and that the field-magnet revolves, carrying the brushes with it. The field now cuts the armature instead of the latter cutting the field, but the result is precisely the same—*i.e.*, current is delivered to the external circuit. By this method,

ALTERNATING-CURRENT MOTORS.

Synchronous Motor.—Suppose that we have two of the single-phase alternators, illustrated in Fig. 30, the fields of both being excited by a separate direct-current dynamo. The two machines, A and B, are driven by one or by separate engines at the same

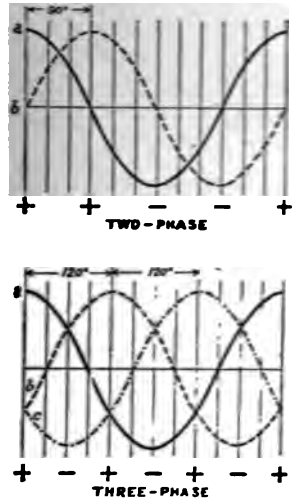


FIG. 39.

speed. The engine is now disconnected from B, and at the same time, by suitable means, the two armatures are connected together. Machine A, being actuated by the engine, will continue to act as a generator. The alternating currents from this, passing through the armature coils of B, will drive the latter machine as a motor. If we let it run "light,"

Polyphase Induction Motor.—Fig. 40 is a complete induction motor as constructed by the Westinghouse Company. The field-magnet, or "stator," shown separately and unwound in Fig. 41, is a hollow, cylindrical frame of cast iron. Inside this is mounted the core, a second hollow cylinder

FIG. 40.—POLYPHASE INDUCTION MOTOR.

built up of annealed steel rings. On the inner edge of this are the slots for the reception of the winding —these slots being entirely open. The complete wound stator is given in Fig. 42.

An examination of Figs. 43 and 44 will show how the rotating field is set up in the stator. The heavy

vertical lines represent a portion of the core of Fig. 41 spread out flat. The heavy lines themselves indicate the teeth or projecting portions, whilst the

FIG. 41.—UNWOUND STATOR.

spaces between them are the slots. Referring specifically to the two-phase arrangement of Fig. 43, three coils of winding *a* are shown in full lines, and

two coils of *b* in broken lines. Each coil has two turns, occupies four slots, and embraces five teeth. If an impulse of current passes through phase *a* in the direction of the arrows, the groups of teeth embraced by this winding will have polarity induced in them as in Row I. of Fig. 43. Those teeth outside the

FIG. 42.—WOUND STATOR.

coils of this phase we may assume to be idle. This positive impulse in *a* is followed by a similar one in phase *b* (see Fig. 39). The teeth embraced by *b* are thus magnetised, as in II. These active teeth are the idle ones of the previous stage. Another impulse now traverses phase *a*, in the opposite direction to the first. Hence the polarity developed is reversed, as in

Phase *b* follows with another negative impulse, effects are shown in Row IV. As a result of four impulses, the N pole at the extreme of Row I. has shifted to the extreme right w IV., and similarly with the other poles. Also, ovement, instead of being a series of steps, is a

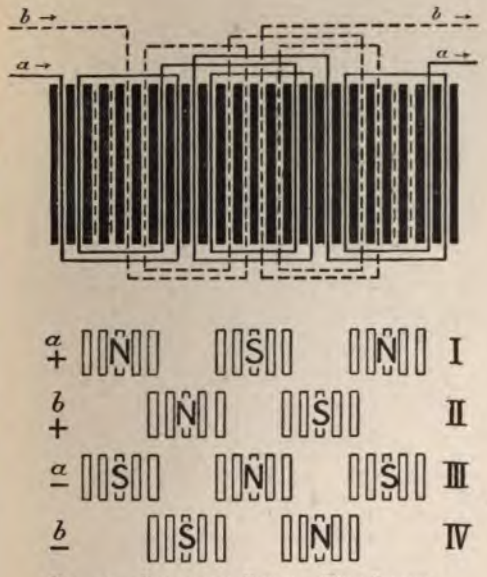


FIG. 43.—ROTATING FIELD. TWO-PHASE.

al one. Thus the entire length of the stator is occupied by broad bands of alternate N polarity, and these bands are in constant on.

. 44 shows in a similar manner the winding for ee-phase motor. The third phase, *c*, is chain-

on the shaft, and the machine loses its simplicity thereby.

Starting. — Small motors, with squirrel-cage rotors, are started by simply connecting up the supply mains by a suitable switch. With larger machines this method is liable to cause a variation in the supply. Hence an "auto-transformer" is used, by which only a portion of the full pressure is applied. When the motor has speeded up, this transformer is cut out, and the mains connected direct. With wound armatures, of course, the starting resistance is placed in circuit, and then gradually cut out.

Single-phase Induction Motor.—Referring to the curves of the three-phase system given in Fig. 39, as we have already noticed, the impulses sent out are alternately positive and negative. Now, a single-phase generator sends out its impulses in just the same manner, excepting that, other things being equal, the impulses do not follow each other so quickly. At the motor end, with a single-phase winding, the effects of two succeeding impulses are represented by I. and III., Fig. 43. In a sense, such a field may also be considered as rotatory, but in either direction. If the armature be started it will rotate as in a polyphase motor, but it will run in either direction. It will not, however, be self-starting, since, with the armature at rest, a pull in one direction is always accompanied by an equal pull in the other. Such motors are rendered self-starting by providing them with an auxiliary winding, in circuit with which is an inductive resistance. The machine is then started by means of a two-position switch, which in the "starting" position places the two windings in parallel. The single-phase

current enters both, but the inductive resistance produces a lag in its winding, so that for the time being a kind of two-phase effect is produced. When the motor has fairly started, the switch is turned to the running position, and the auxiliary winding cut out.

CHAPTER IV.

TRANSFORMERS AND MOTOR-GENERATORS.

Transformers.—The commonest example of a transformer is the ordinary induction coil. In this a few turns of stout insulated wire, the "primary," are wound over an iron core, and over this winding is placed the "secondary"—a large number of turns of very fine wire. When the primary circuit is completed or broken a powerful magnetic field is set up or withdrawn, resulting in the setting up, in the secondary, of E.M.F.'s so high as to discharge across the terminals of this winding in a series of brilliant sparks.

The primary being of very low resistance, even a small E.M.F. can produce a powerful current therein. We, therefore, furnish the apparatus with a large current, and it gives us back a high E.M.F. We might reverse the process—make the primary of a great length of fine, and the secondary of a few turns of stout, wire. The battery, in this case, will need to have a high E.M.F., in order to set up even a small current through the high resistance of the long coil. The setting up and the removal of the lines of force will then induce, in the low-resistance winding, a powerful current.

As we have seen in a previous chapter, electrical energy consists of two factors—current and E.M.F. Hence the same amount of energy may consist of

these two factors in very different proportions, *i.e.*, low E.M.F. and large current, as in the ordinary arrangement of the primary of the induction coil, or *vice versa*, as in the secondary; but the energy represented by the product of the two factors in the one circuit may be same as the similar product in the other. Theoretically, they should be equal; but the induction coil is an inefficient form of transformer,

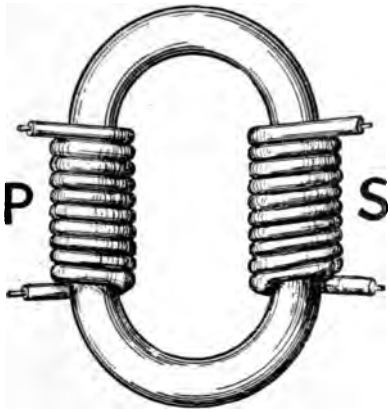


FIG. 46.

and the energy given out is much less than that put in.

Fig. 46 gives the principle of a simple type of transformer—a slight modification of the ring of Faraday. A soft iron core of circular section carries two coils—P, the inducing or primary, and S, the secondary. Imagine a battery applied to P. A certain number of magnetic lines are set up, and these find a complete circuit through the mass of the core.

The lines thus necessarily pass through the interior of the coil, S, and in so doing they set up an E.M.F. therein: similarly, on breaking the primary circuit. This "threading" is thus precisely the same action as the "cutting" of the lines by the armature conductors of the dynamo.

Ratio between Primary and Secondary E.M.F.'s.—Suppose that both primary and secondary coils are of exactly the same kind and length of wire, and that each makes ten turns round the core. Suppose also that the most favourable conditions exist—as to quality of iron and many other factors—and that there is no loss in conversion, *i.e.*, that the apparatus is perfect. The E.M.F. in the primary sets up a current therein of a certain value, and this, in its turn, sets up a certain number of magnetic lines. Under the above conditions, these lines, in threading the secondary, will induce therein an E.M.F. of precisely equal value to the primary E.M.F. That is to say, when the number of turns in the two windings are alike, the induced E.M.F. is equal to the inducing E.M.F. Further, as the energy in the one circuit is equal to that in the other, it follows that the two currents will be equal—that is, when the secondary circuit is closed and its resistance at its lowest value.

If the secondary has twenty turns, and the primary ten, the magnetic lines will thread twice the length of conductor, and the induced E.M.F. will be twice as great. The secondary current then cannot exceed half the value of the primary current. Or if the secondary has a hundred turns to the primary ten, the induced E.M.F. will be ten times as great, and

the maximum current reduced to one-tenth, and so forth. If, on the other hand, the secondary has less turns than the primary, the induced E.M.F. will be less than the inducing, but the maximum current will be correspondingly increased. The relation, then, between the E.M.F.'s in the primary and secondary circuits is in direct proportion to the number of turns in the two windings. Transformers constructed to give out a higher E.M.F. than that put in are termed "step-up" transformers; whilst those which give out a lower E.M.F. than that put in are "step-down."

The conditions assumed, of course, do not obtain in practice. There is inevitably a loss in conversion. The transformer, however, is a remarkably efficient piece of apparatus—an efficiency as high as 97 or 98 per cent. being obtained.

Alternating Currents in Primary.—The induced E.M.F. is set up only when the primary is opened or closed. If, however, instead of taking off the battery (break), we simply reverse it, we shall practically double the primary E.M.F.—for the effects of the withdrawal of the battery and of joining it up in the reverse direction are additive. That is, instead of varying from zero to (say) 10 volts positive, it will now vary from 10 volts positive to 10 volts negative. The secondary E.M.F. thus set up will be correspondingly increased. The feeding of the primary by alternating currents is directly analogous to this reversal of the battery, the withdrawal of the magnetic lines being followed by their establishment in the opposite direction. The cycle then varies from a positive maximum, through zero, to a negative maximum, or equivalent to the cutting

of twice the actual number of lines of force, just as, in the case of the battery, it is twice the actual E.M.F. of the latter.

Fig. 47 shows a transformer constructed by the General Electric Company. This, like the simple form of Fig. 46, is of the closed magnetic circuit type, although, for mechanical reasons, the circular form of core is departed from. Half the primary and half the secondary are wound on each limb, the former being next the core and the secondary outside. The

FIG. 47.

core is laminated so as to be continuous in the direction of the magnetic lines, but broken in that of the eddy currents. The transformer thus constructed is generally placed in an iron case, as in Fig. 48.

Other types are the core or polar transformer and the shell. In the former the magnetic circuit is not complete, being built on somewhat similar lines to the induction coil. In the shell type the iron is outside, and encloses the windings, except their extremities. One of this type is shown in Fig. 49.

Transformers for Continuous Currents.—The apparatus just described is clearly only available for use with alternating currents. But we may need a similar device for varying the factors E and C when using direct currents. Suppose we desire to energize an experimental electro-magnet, requiring two amperes and having a resistance of five ohms, and that a public supply of direct current is available at 200 volts. To urge two amperes through our electro-

FIG. 48.

magnet we need ten volts. But the pressure of 200 volts will urge this current through 100 ohms, whilst our resistance is but five. Hence, if we use the public supply, we must insert a resistance of 95 ohms in circuit with our apparatus. Now, for constant use, this is a very wasteful arrangement, as we are using $2 \times 200 = 400$ watts, where we need only $2 \times 10 = 20$ watts. Of course, the proper method is to wind the electro-magnet with finer wire, so as to need a smaller current. The high resistance will then fit

in with the E.M.F. at our disposal. However, in the case we have assumed, the supply is unsuitable. For this purpose, therefore, it may be economical to use a motor-generator or motor-dynamo.

Motor-Generator.—This is simply a motor and a dynamo coupled together. For the above experimental purpose, the dynamo must be of such dimensions and winding as to be capable of furnishing the required output, 2 amperes × 10 volts = 20 watts,

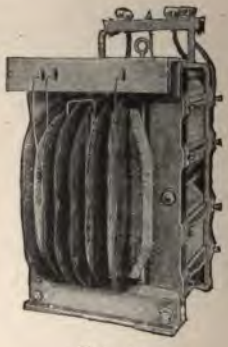


FIG. 49.

when running at a certain speed. Assuming the efficiency to be 80 per cent., we shall need to put in 20 + 5 = 25 watts; or in other words, the motor which is to drive the generator must have an output of 25 watts when running at this particular speed. With the same efficiency in the motor, we must supply the latter with 31·25 watts. But one factor of the supply is already fixed, viz., the E.M.F., which is 200 volts. Hence the current must be $\frac{31 \cdot 25}{200} = \cdot 15$ ampere, and the winding must be arranged to sui

The efficiency of the combination is thus $\frac{20}{31 \cdot 25} = 64$ per cent. A "dynamotor" is used for a similar purpose, and is a machine with a single field and single armature-core, but the latter has two windings, each of which is led to a separate commutator. It is not, however, so flexible an arrangement as the motor-dynamo, in which both machines are entirely independent.

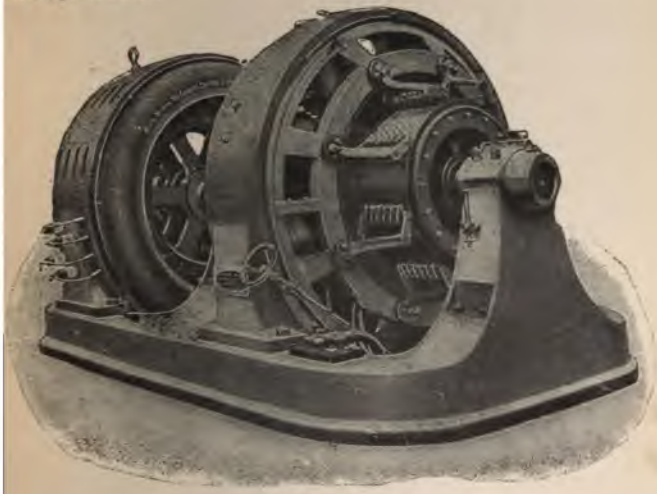


FIG. 50.

We have considered these machines as continuous current transformers only, but it will be readily understood that a change may be required from alternating to direct, or *vice versa*. In the former case the motor, and in the latter the generator, will be an alternating current machine. For this purpose a "rotary converter" is also used. This somewhat

resembles a dynamotor in that it is a single machine, having a single field in which a single-wound armature rotates. This winding is connected to slip-rings on the alternate current (single or polyphase) side, and the same winding is connected at the usual points with a commutator on the direct current side.

A General Electric motor-generator is illustrated in Fig. 50. This is used to transform from polyphase alternating to direct current. The generator, shown in the foreground, is an eight-pole machine, and is driven by a three phase induction motor.

CHAPTER V.

AMMETERS AND VOLTMETERS.

AMMETERS and voltmeters, generally speaking, are low and high resistance galvanometers, graded to read in actual units of current and E.M.F. The reason for the low resistance of the one, and the high resistance of the other, is as follows: To measure the current strength in any circuit the measuring instrument is placed directly in that circuit. If, then, the ammeter has considerable resistance, its introduction into the circuit will seriously cut down the current, so that we shall measure not the original current but a much diminished one. Hence the resistance of the ammeter is kept as low as possible, and, indeed, is generally inappreciable. On the other hand, when we measure E.M.F., or the difference of potential between two points, we insert the voltmeter across these points. If, for instance, we desire to know the P.D. across the terminals of a glowing incandescent lamp, we place the voltmeter across it—in parallel with it. Now, if the instrument were of low resistance, it would rob the lamp of some of its current, and this would cause an alteration in the P.D. at the lamp terminals. Therefore, the higher the resistance of the voltmeter the better—its introduction across any two points of a circuit then causing no appreciable variation in the P.D. it is desired to measure.

Types of these instruments are very numerous; but we shall confine our attention to one or two makes in actual use in the battery and instrument rooms. One of these is the D'Arsonval type. The usual arrangements of a galvanometer are here reversed—the magnetic field being stationary and the coil movable. This constitutes the D'Arsonval principle, and is applied to both voltmeters and ammeters.

"Stanley-D'Arsonval" Instruments.—A volt-

FIG. 51.

meter of this type, as manufactured by the General Electric Company, is illustrated in Fig. 51; whilst Fig. 52 shows the instrument on a larger scale, with the cover removed so as to expose the movement. A large permanent magnet, of horse-shoe shape, has two pole-pieces attached to the inner faces of the poles. These pole-pieces are hollowed out to form a kind of incomplete tunnel in which a cylinder of soft iron is fixed. The diameter of the latter is less than that of the tunnel, and in the annular space thus

formed the coil, pivoted as shown, is free to turn. The coil, rectangular in shape, is wound on a light metal frame, which forms a complete circuit for the eddy-currents set up when the system moves. To this is due the "dead-beat" action of the instrument. When the coil turns, the eddy-currents circulating in

FIG. 52.

the frame act as a kind of magnetic brake and cause the pointer to move steadily to the proper deflection instead of overshooting the mark, and then vibrating for a sensible time before settling down to the particular reading. The movable coil is kept in its zero position by two spiral springs fitted at the ends—one of which is just visible above the front bridge-

piece of Fig. 52. Besides furnishing the control of the instrument, these springs serve to convey the current to the coil. The movement of the latter under the influence of a current will be easily understood. The lines of force set up in the coil tend to set themselves parallel with the lines of the field provided by the permanent magnet.

It is usual in these instruments to allow about a hundred ohms per volt to be measured—that is, a voltmeter reading up to 100 volts will have a total

FIG. 53.

resistance of 10,000 ohms. This is obtained by connecting a high resistance in series with the moving coil. The scale is from from 20 to 140 volts.

This instrument is also mounted in a wooden case to serve as a portable voltmeter, as in Fig. 53.

The ammeter is practically identical with the voltmeter except that it has a low resistance shunt joined across the moving coil. The main current, therefore, passes through the shunt, only a small portion going through the coil. This is an advantage, as the heavy

mains need not be taken to the instrument itself—thin leads serving as the connection between the ammeter and its shunt.

Cell-testers.—Fig 54 is a "cell-tester," or voltmeter for use with single secondary cells. Its zero is in the centre of the scale and extends to three volts on either side. This also is on the moving-coil

FIG. 54.

principle, and is made by Messrs. Nalder Bros. and Thompson.

Fig. 55 is a General Electric Company's pocket voltmeter, reading from 0 to 3 volts—also intended for use with secondary cells. It will be seen that a point protrudes from the lower part of the case. This serves as one end of the coil, and is gently pressed upon one terminal or plate, whilst the peg with its connecting cord serves as the other contact.

Weston Instruments.—These also are constructed on the moving-coil principle, and are dead-beat in action. Figs. 56 and 57 represent a portable form of voltmeter and ammeter, whilst Fig. 58 shows the movement, much enlarged.

The voltmeter here shown has two coils and two scales. The ends of the long coil are brought to the two front terminals, and its scale is graded from zero

FIG. 55.

to 150 volts. The scale of the short coil is zero to 15 volts. Its ends are connected to the right-hand terminal (which is therefore common to both coils) and to the upper terminal on the left, the latter being covered with rubber and engraved "15." The small press-button on the right is a contact key. The circuit of both coils is normally broken, and the depression of this button completes the circuit. By

giving it a quarter-turn this connection can be permanently closed. The auxiliary resistance is mounted in the base of the instrument.

The ammeter will need no further description. The scale of this particular instrument is 0 to 25 amperes, and the shunt, like the auxiliary resistance of the voltmeter, is enclosed in the base.

Recording Instruments.—The voltmeters and ammeters just described indicate, of course, the values of E.M.F. or current at a particular instant—they

FIG. 56.

give no indication of what these values have been. In some cases, however, we need to know, not only the particular value reached by the current, but how long it has lasted, or how much electricity has passed. For this purpose recording instruments are used.

A recorder manufactured by Messrs. Elliott Bros. is illustrated in Figs. 59 and 60, the latter being an inside view. In the upper part of an iron case is a moving-coil galvanometer. The coil system, however, carries a long arm hanging vertically down-

wards instead of the usual pointer. A current passing through the instrument will move this arm to the right or left according to its direction. Occupying the centre and lower portion of the case is a clockwork movement which propels forward a broad paper band ruled with faint lines parallel to its length, and also across the paper in an arc of a circle whose centre is the pivot of the hanging arm—that is, if the end of the arm were drawn quite across the paper

FIG. 57.

band whilst the latter were stationary, it would describe one of these lines. The centre line parallel with the length of the paper is the zero line, and those on either side of it correspond to various strengths of current. The instrument illustrated is actually a recording voltmeter, but the recording arrangement is precisely the same for an ammeter. The paper travels downward at a uniform rate—the standard speed being one inch per hour; but other speeds are used for certain requirements. The end

of the vertical arm carries the recording pen, consisting of a light nib hanging in a forked piece. The clock runs for eight days, and is wound up by means of a lever movement at the right-hand side. Fig. 60 shows the clockwork being wound up.

Electrolytic Meter.—The record given by the

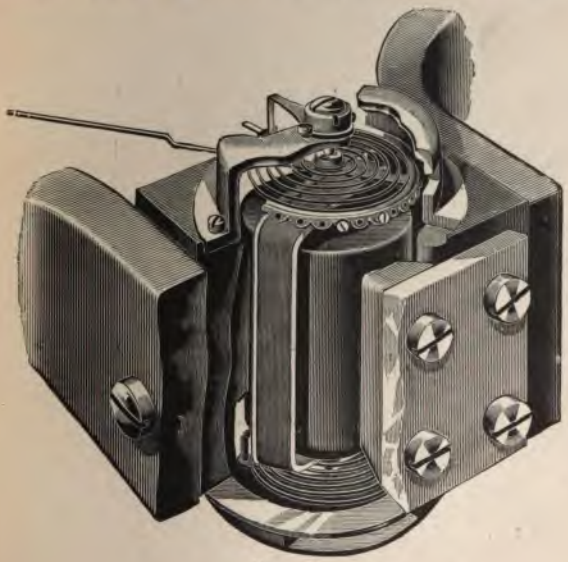


FIG. 58.

instrument just described shows all the variations in the current, and its value at any particular time. To ascertain the total amount of electricity which has passed, it is necessary to integrate the curves traced on the moving band. Other instruments are arranged to show only the total amount without reference to its varying values. Wright's electrolytic meter is of this

class. The instrument, illustrated in Figs. 61 and 62, is constructed by the Reason Manufacturing Company.

FIG. 59.

A hermetically-sealed glass tube, with a bell-shape extension, P, at its upper end, is filled with the elec *trolyte*—a solution of mercurous nitrate. The uppe

portion of the tube opens into this bell-shaped receptacle, the edge of the former being slightly above the bottom of the latter, and in the annular space

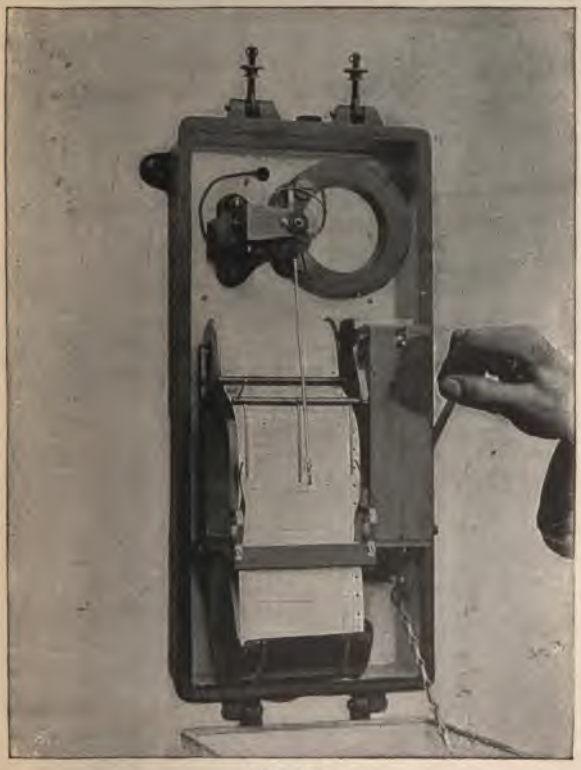


FIG. 60.

thus formed, the anode, A, of metallic mercury, lies. Fig. 62 is a side view of the apparatus taken out of the case. Communicating with the receptacle is a

reservoir, F, filled with mercury. This acts on the

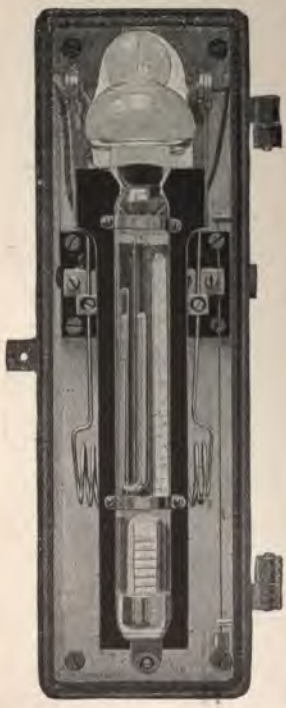


FIG. 61.

FIG. 62.

"bird-fountain" principle, and keeps the level of the

anode, A, constant. The cathode, C, is a tube of platinum, open at both ends.

When a current passes through the apparatus from A to C, the electrolyte is split up and metallic mercury is deposited on the cathode, from which it falls into the inner graduated tube, G. Fresh mercury, of course, dissolves from the anode, and keeps up the strength of the solution. The tube, G, is a siphon, which, when entirely filled, automatically empties itself into the outer tube, which also is provided with a scale, S. Thus the quantity of mercury in the outer tube and in G is a measure of the quantity of electricity which has passed.

A fine wire resistance is in series with the electrolytic cell, and in parallel with the two is a short coil of stout wire—the ends of which can be seen on either side of the lower part of the case in Fig. 61. Thus only a small fraction of the total current passes through the electrolyte.

The whole arrangement is suspended from the upper part of the case, and when the tubes, S and G, are entirely filled, the apparatus is simply inverted. The mercury then falls back into the receptacle and the reservoir, F, and the meter is ready for a fresh run.

CHAPTER VI.

Evolution of Secondary Cell.

IN the primary cell we assemble certain materials —acid, zinc, etc.—having a strong chemical affinity for each other, and the arrangement is at once capable of furnishing current. In the secondary cell the materials used have, at the initial stage, no affinity for each other; but on passing current through the cell the originally inert materials are replaced by new ones, between which chemical affinity exists. The cell is then ready to give out current. The difference, therefore, between the two, is that the primary yields electrical energy as soon as its constituents are assembled, whilst the secondary is unable to do this until current has been passed through it. Hence the name.

Further, in the primary cell, when all the materials have been used up or have formed fresh compounds, it is necessary to mechanically re-charge it, by withdrawing the spent materials and products of the chemical action and substituting fresh ones. This involves the absolute taking-to-pieces of every cell, washing out, renewing zincs, scraping carbons, and replacing with fresh parts, acids, etc., unpleasant to handle. The secondary cell, on the other hand, is re-charged by simply passing current through it—as at the initial operation—in the reverse direction to the current given out. Thus the re-charging of the

primary is a mechanical, troublesome, and disagreeable operation, whilst that of the secondary is purely electrical, and is attended by no handling of the cells—the latter remaining absolutely untouched.

Now, this difference is a very important one. To keep in working order the battery equipment of a large telegraph office having, say, a thousand primary cells, is a costly matter, both for labour and for fresh material. The labour, too, as we have seen, is of a dirty and unpleasant nature. The supersession of the primary battery by other methods for the supply of current is, therefore, in the natural order of things.

In America the dynamo itself is largely employed, connected direct to the apparatus—separate machines being used for the different voltages. The advantages of this plan are obvious, especially if the dynamo is driven by a motor supplied with current from a public network. Instead of the dirty chemical means, we have a rotating machine, perfectly clean, occupying but a tithe of the space otherwise required, and all but noiseless. When the dynamo is engine-driven, of course, a little more dirt and some noise are generally inevitable, but the arrangement is still of great simplicity. The disadvantage is the possible stoppage of the generator, owing to any fault in the latter, or to the failure of the driving machinery, when all current is at once cut off. This is guarded against by the provision of spare machines. This method, however, of using the dynamo direct has not found favour in British telegraphy, but wherever primaries are discarded the secondary battery has been adopted. Assuming a dynamo to be necessary (*i.e.*, where the public supply is unsuitable), this plan, of course,

introduces a complication which is absent from the direct-coupling method, but it has the great advantage that it is not dependent on continuously-moving machinery. Further, if cells of even moderate size are used, their capacity is generally so considerable that a large margin is easily obtained. In practice, as far as the number of cells is concerned, about 45 per cent. more are installed than are in actual use; and these are thus available for charge, as we shall see later.

The whole case of primaries *v.* secondaries is, of course, a matter of cost. In small offices the former are naturally the cheaper, whilst in very large ones the installing of the latter results in a very considerable saving. However, we are not concerned with this aspect of the question, and we will now consider the evolution of the secondary cell.

Principle of Secondary Cell—Electrolysis.—The root of the electro-plating industry is the phenomenon of electrolysis, or electric analysis. Solutions of metallic salts are split up when a current of electricity is passed through them, the metal appearing at the pole or electrode by which the current leaves, and the other constituents of the solution appearing at the electrode by which the current enters. The two electrodes are termed the kathode and the anode respectively, and the solution thus suffering decomposition is termed an electrolyte.

One of the simplest instances of electrolysis is that of copper sulphate. The anode must be of copper; the kathode may be of carbon or other conductor. Both electrodes may conveniently consist of strips of copper. These are immersed in a solution of the salt. On the passage of a current the liquid is

decomposed, metallic copper being deposited on the kathode, whilst the "sulphion" (SO_4) liberated at the anode combines with fresh metal from the latter. The anode thus dissolves away, whilst the other electrode increases in weight, the solution remaining at the same strength. Hence the necessity for an anode of the same metal as that deposited.

Water is an electrolyte: being, however, a bad conductor, a little sulphuric acid is added to increase its conductivity. When such acidulated water is traversed by a current it is similarly split up into its constituent oxygen and hydrogen. When elements are thus set free—in their *nascent* ("just born") state —they have a much greater chemical activity than they possess later. The electrodes in this experiment therefore are of platinum, a metal having no affinity for either of the elements set free. The latter are thus prevented from entering into combination with the electrodes, and oxygen rises from the anode (by which the current enters the solution) and hydrogen from the kathode. Both gases collect in tubes suitably inverted over the platinum strips.

Now, after allowing the current to pass for some time, if we disconnect the battery and put in its place a suitable galvanometer we shall find that the electrolytic apparatus is capable of acting as a battery. The decomposed gases recombine, and the act of recomposition liberates electricity. We have, indeed, the converse operation of the first. In the first, electricity was absorbed in splitting up the electrolyte; in the second, the separated members re-unite and liberate electricity. Grove's "gas battery" is practically identical with this apparatus. The resulting

effects are very slight, but very valuable from a theoretic point of view. It is indeed the germ of the "secondary" cell. The terms "accumulator" and "storage cell" are of rather doubtful value, as it is clearly to be seen that we do not accumulate or store electricity, but chemical energy.

The earliest worker in this field was Planté. He however employed electrodes of lead, with which the liberated oxygen immediately combines. He also employed comparatively large plates, so as to offer an increased surface for action. The anode, therefore, becomes covered with the peroxide of lead (PbO_2); but the hydrogen appearing at the kathode —having no affinity for lead—is set free. After the charging current has been on for a certain time free oxygen gas begins to pour off the surface of the anode. This indicates that the plate is oxidised to its full extent and can take up no more. The arrangement will then act as a battery cell—a current passing through the external circuit, from the anode to the kathode, or in the reverse direction to that taken by the charging current. The anode is better known as the positive, and the kathode as the negative, plate.

The effect, then, of a complete charge is to cover the positive plate with lead peroxide—the negative being unaffected and remaining plain lead. The effect of discharge is to partially deoxidise the positive and to partially oxidise the negative—both plates being brought to the same chemical state.

CHAPTER VII.

SECONDARY CELLS—GENERAL.

Forming.—The amount of electricity obtainable from a cell with plain lead plates, even if these are of a fair size, after a first charge is very small indeed, and quite useless for any practical purpose. With each charge, however, the capacity of such a cell increases. Hence, in order that the cells may have sufficient capacity for commercial use, the plates are "formed" by repeated chargings, the latter being given in alternate directions. The reason for the increased capacity is that the continued chemical action eats deeper and deeper into the positive plates, making them porous or spongy, and thus increasing their active surface. By reversing the charging current, both plates are equally affected.

These repeated chargings, necessary to get the plates into such a condition as to give out a practical amount of electric energy, are very costly, and cheaper means have been sought to attain this end. A mechanical means consists in allowing a vessel full of molten lead to cool down until the metal is about to solidify, when a hole is made in the vessel and a large amount of the still-liquid metal runs out. That remaining behind will be of a spongy nature, and is thus suitable for the purpose. Another (chemical) means is to treat the plates with a mixture of nitric

and sulphuric acids. This eats into the plates and gives a greater surface.

Pasting.—Quite a different and a very successful method of preparing the plates is to paste them with the oxide of lead—as originally suggested by Faure. A stiff paste of red lead, Pb_3O_4, and sulphuric acid, is smeared over the surface of the plates and allowed to dry. To-day this method is employed with the positives, but litharge, the monoxide, PbO, is substituted for use on the negatives. The charging current has thus to deal with material much looser in texture than solid lead. Thus, of a single molecule of water, one atom of oxygen released at the positive plate is now sufficient to produce two molecules of the peroxide; whilst the two atoms of hydrogen at the negative engage with the oxygen of a molecule of the monoxide, which is thus reduced to metallic lead. Plates thus made up, after a single charge, are ready for work without the preliminary "forming." The great difficulty, however, with plates of this type, is to get the paste to adhere. The whole surface was deeply scored, punched with holes, and otherwise roughened, in order to afford a grip for the paste, which when dry becomes brittle, contracts, and falls away. The plates now are "grids" or containing frames in which the paste is firmly held—the precise form to be described in a later chapter: such are termed Faure or pasted plates. Plates of the Planté or formed type are also used, generally for positives. The lead is then carefully selected and is made up into grids, so as to offer a large surface for action, but the formation of the grid is of a stouter and stronger type. These have the advantage of thorough

homogeneity and greater mechanical strength, and are therefore better adapted for rough usage, and can stand excessive overloads.

Voltage.—The E.M.F. of the secondary cell is about 2 volts for any size. After a thorough charging, this rises as high as 2·5 volts, but speedily falls. The voltage then continues steady at 2 volts for all working purposes until the limit of its capacity is being reached, when the E.M.F. again falls. At about 1·9 the extreme limit is attained, and no further discharge should be taken. The voltmeter, therefore, affords a ready indication of the condition of the cell. For use in making this test, a "cell-tester," or low-reading voltmeter, is employed. These instruments usually have a central zero, with a scale indicating up to about 3 volts on either side, so that the direction of the current is immaterial. Such an instrument is described in Chapter V., and illustrated in Fig. 54.

Specific Gravity — Hydrometer. — Another means of gauging the condition of the battery is by noting the specific gravity (sp. gr.) of the electrolyte. The sp. gr. of a liquid is the ratio of its weight to that of an equal volume of water. Thus, if a pint of fresh water has a weight denoted by 1, and a pint of sea-water a weight of 1·024, the sp. gr. of the latter is $\frac{1{\cdot}024}{1} = 1{\cdot}024$. Liquid mercury has a sp. gr. of 13·6. This is equivalent to saying that sea-water is 1·024 times, and mercury just over thirteen and a half times, heavier than fresh water. The dilute acid used in the cells has a sp. gr., when the latter are properly charged, of about 1·210. When a fair dis-

charge has been drawn off, this falls to about 1·170. further discharge persisted in, the sp. gr. will fall sti

FIG. 63.

FIG. 64.

lower; but when this occurs we are injuring th cells. On charging, the sp. gr. again rises, to fa

again on discharge. Hence the measure of the sp. gr. of the electrolyte is a very valuable indication of the state of the battery, and, together with the voltage, furnishes a ready index to what is going on.

To measure the sp. gr. the hydrometer is used. The forms illustrated in Figs. 63 and 64 consist simply of a glass tube, narrow at the upper and enlarged at the lower part—the latter end being weighted. When the instrument is placed in any liquid, the lighter the latter the deeper the hydrometer sinks, and *vice versa*. The weighting serves to keep the instrument upright. The narrow part carries a scale engraved as shown, "1000" being taken instead of "1·000," thus avoiding the fractional form. The scale in Fig. 63 is from 1050 to 1350, and that in Fig. 64, 1150 to 1250. The latter limits are quite wide enough, and give a more extended space for the intermediate values. Thus, when it is desired to test the sp. gr. of any liquid, the hydrometer is simply placed therein, and the degree of its submergence is then read off the scale.

Theory of Secondary Cell.—With electrodes of plain lead standing in pure water, the effect of charging is to liberate oxygen at one plate, with which it combines, and hydrogen at the other, whence it is given off. When fully charged, therefore, the positive plate is covered with lead peroxide PbO_2, and the negative is plain lead.

On discharge, the effects of electrolysis are reversed, hydrogen appearing at the positive and oxygen at the negative plate. The former robs the peroxide of some of its oxygen, whilst the latter combines with the plain lead of the negative. When

thoroughly discharged both electrodes are brought to the same condition. Thus the operations of charge and discharge would seem to consist in the transfer of oxygen from one plate to the other.

This explanation, though not altogether incorrect, is incomplete. It assumes that the electrolyte is simple water, or that the acid present does no more than to increase its conductivity. It would appear, however, that during discharge, not only is oxygen carried to the negative plate, but that, the acid itself being broken up, the "sulphion" particles (SO_4) unite with the lead of both plates; whilst the hydrogen thus freed combines with the oxygen of the positive plate, which we have not yet accounted for. By the operation of discharging, then, both plates become coated with the normal lead sulphate ($PbSO_4$), and water is formed—or rather, the electrolyte is robbed of some of its acid. The effect of the charging current is then to restore the sulphion to the liquid, which sulphion engages with the hydrogen of the water, re-forming sulphuric acid, the oxygen going to peroxidise the positive plate. This is borne out by the fact that during discharge the electrolyte becomes more dilute—*i.e.*, has less acid, as shown by the falling of its density, and that the effect of charge is to cause the density to rise, by the addition of the acid thus re-formed.

Sulphating.—As we have seen, the normal effect of discharge is to produce lead sulphate on both positive and negative plates, and that of charge to change this to lead peroxide and plain lead respectively. If a battery is repeatedly subjected to prolonged over-discharge or insufficient charge, patches

of a white substance appear on the surface of the plates. This is the effect known as "sulphating," and is always the sign of improper or careless treatment. The white patches are an abnormal sulphate of lead, hard and insoluble. The normal sulphate formed on discharge not having been cleared off (charging not being sufficiently prolonged), it appears to alter its composition somewhat, and to change into the obstinate variety, which strongly resists the action of the succeeding charging current. To prevent the formation of this sulphate, over-discharge should be carefully guarded against, and cells should not be allowed to stand idle for long periods unless fully charged. The remedy for sulphating, where it has set in, is prolonged over-charge, so as to break down the troublesome compound.

Buckling.—The effect of sulphating is to insulate those portions of the plate where it appears. The whole surface of the affected plate does not then equally share in the work, and varying current densities are set up in different regions of the plate. This causes the latter to warp or buckle. The pellets of paste in the neighbourhood of the bending are thus loosened, and are liable to project beyond the surface of the grid, and in time either bridge over adjacent plates—setting up a short-circuit—or to fall between them. Slight buckling may also be due to variation or want of homogeneity in the structure of the plate itself. The grids are always placed with their lower edges well above the base of the cell, so that detached pellets may fall to the bottom and thus do no harm. Excessive charge and discharge are fruitful causes of buckling, and should therefore be avoided.

67515

Capacity; Efficiency.—The capacity of a cell is expressed in ampere-hours, or the product of the current into the time it lasts. Thus one capable of furnishing 20 amperes for 10 hours, or 40 amperes for 5 hours, has a capacity of 200 ampere-hours. Cells, however, do not give the same capacity at all rates of discharge. There is for each size a certain value of current which will give the maximum capacity, and the more the discharge current exceeds this value the less the capacity. Similarly with charge, there is a certain rate at which the product of the current and the time will be the least. A feeble current or a disproportionately powerful one is uneconomical.

The ratio of discharge to charge (ampere-hours) is the efficiency of the cell. Under the best conditions it does not exceed 60 or 70 per cent. The secondary battery is therefore by no means an efficient piece of apparatus.

CHAPTER VIII.

SOME TYPES OF CELL.

THE cells in use for telegraph installations set up during the last few years are those of the Hart Company, of Stratford, E. The following is, therefore, mainly devoted to a description of these. However, as other makes have been and are employed in older installations, and for various other purposes, in the telegraph service, short descriptions are added of the cells manufactured by the Chloride Electrical Storage Company, and by the Electrical Power Storage Company.

Hart Cells: Construction of Plates.—These plates are of the Faure or pasted type. The lead for the grids is carefully purified and refined to ensure the absence of impurities which, in the working of the cell, would soon manifest themselves in rapid deterioration of the battery. The oxides used for the paste are specially prepared, so that the latter is of such a nature that, whilst taking a firm hold of the plate, it still has the required degree of porosity to ensure free circulation of the electrolyte into the interior of the plate. Fig. 65 gives details of the grids. In the upper left hand is a portion of an unpasted negative—the piece measuring about 3 ins. by $3\frac{1}{2}$ ins., and beneath this is a smaller piece of unpasted positive. It will be seen that each of these is broken in two; the left-hand portions represent

the grids as they appear in the first stage, and the right-hand portions as they appear later. On the extreme right are two sections, X and Y, of the

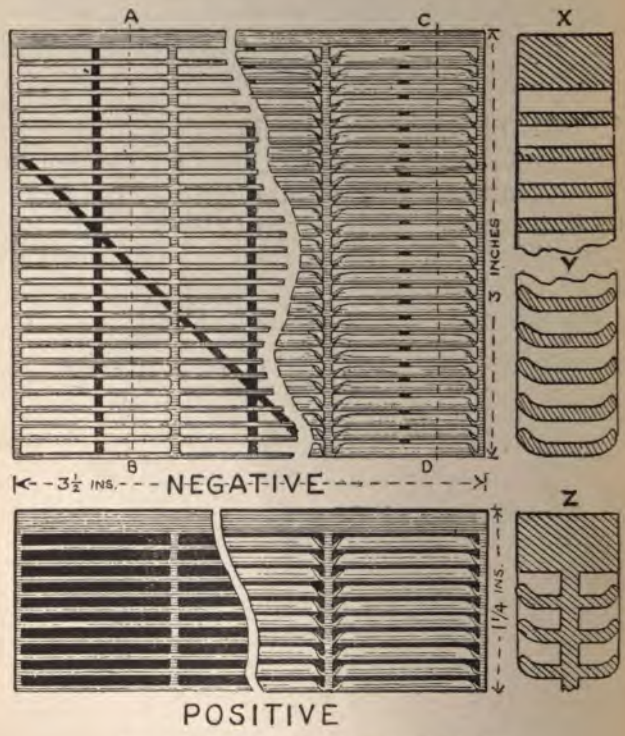


FIG. 65.—DETAILS OF HART CO.'S PLATES.

negative, taken through A B and C D respectively, and one, Z, of the positive grid.

The main framework of the negative consists of a number of vertical ribs, shaded (not black) in the

figure, and horizontal ones at top and bottom. Across the vertical ribs is a series of thin lead strips or shelves, forming, with the stouter upright ribs, an extended grid-iron arrangement. Between adjacent shelves, or horizontal strips, are the spaces for the insertion of the paste. To provide additional strength to the structure, another vertical strip is inserted between each vertical pair. These added strips, shown in black, do not extend from face to face of the plate, but simply form a central portion or web. In the regions of the corners of the plate similar strips are placed obliquely, as shown. The right-hand portion of the plates illustrate the method employed to keep the paste in position. The need for some such device will be apparent after a little consideration. Imagine the spaces in the left-hand portion to be filled with paste ; the latter, on drying and hardening, tends to contract slightly. Hence each pellet of paste, occupying a position between two of the "shelves," is liable to loosen slightly, and thus to some extent quit its hold of the metal of the grid. If the entire pellet becomes loose it will be held by the central vertical rib alone. If the pellet keeps in one piece it will remain in position ; but this is by no means to be depended on, for the pellet is weakest at the central region by reason of its being pierced by the central rib. It will, therefore probably break in halves, and the slightest movement will cause both pieces to fall out. To prevent this, the following plan is adopted : Immediately after the grid has been pasted, and the apertures thus filled, the complete plate is subjected to a rolling pressure, applied (in reference to the figure) from the bottom

of the plate, upwards. The result is, that the thin horizontal strips, or shelves, on both sides of the grid are bent upwards. The cavities, therefore, instead of having a rectangular section, are curved, so that it is impossible for the paste to escape. The

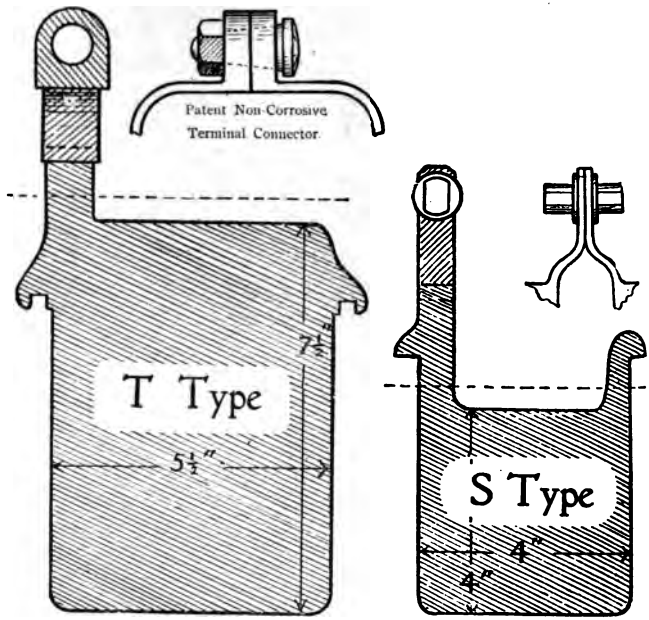


FIG. 66.—HART CO.'S PLATES AND CONNECTORS.

compression, too, forces paste and metal into thorough and intimate contact, so that the dry and finished plate appears to the eye one compact and solid mass. The bending over of the edges is shown in the right-hand portions of Fig. 65, and the enlarged section, Y, indicates the altered shape of the cavities.

The positive grid is similar to the negative, but is slightly thicker and much stronger. The black inner strips which strengthen the negative are extended to form a continuous web at the central region of the positive, as indicated by the full black spaces, and by the enlarged section, Z. After pasting, the rolling process is applied and the edges of the horizontal strips bent over, as in the case of the other plate.

It will readily be seen that, in addition to the paste, there is a large surface of lead itself exposed. Hence, for the first few charges, there is a Planté effect—that is, the capacity of the cell increases as peroxide is formed on this exposed surface.

Two types of cell, the "T" (or traction type) and the "S," are installed for telegraph purposes; and by the employment of varying numbers of plates, cells of five different capacities are obtained: two of the S type, of 18 and 27 ampere-hours, and three of the T, of 45, 72, and 90 ampere-hours. These are all in glass boxes. Fig. 66 shows the dimensions and other details of the plates employed in the two types of cell, also the means by which the different cells are coupled together.

Hart T-Type Cells.—One of these is illustrated in Fig. 67. The plates measure approximately $5\frac{1}{2}$ inches wide by $7\frac{1}{2}$ inches high, and each is furnished with two projecting lugs, one on either side—and by means of these the plates are supported. Following the usual practice, there is one negative in excess of the positive plates: so that the outer ones are always negative and the total an odd number, 5 plates forming the 45 ampere-hour size, 7 the 72, and 9 the 90 ampere-hour size. All the positives are united to

form a set by a stout lead "bus-bar" on to which the plates are cast or melted, and similarly with the negatives. Thus, in a 7-plate cell, the three positives are all connected together by this means, and the connecting-bar carries a lug for terminal purposes. This lug is "burned" on to the bus-bar by means of

FIG. 67.—HART T-TYPE CELL.

the oxy-hydrogen flame. The three plates, the bar, and the lug, thus form the positive section. The four negatives are similarly joined, and with their bar and lug form the negative section. The two bus-bars of each cell are painted red and black to denote the positive and the negative respectively.

The projecting lugs at the sides of the plates rest

on two sheets of glass which are stood on edge inside the glass box itself. On the floor of the latter a square wooden frame is placed, and the glass sheets are stood on end in a couple of saw-cuts in two parallel sides of the frame. The other two sides each carry two upright wooden pieces, and these latter are united across the top of the plates by two horizontal pieces. All this wood-work is, of course, previously soaked in paraffin wax, or otherwise rendered im-

FIG. 68.—METHOD OF SUPPORTING PLATES.

pervious to the action of the acid. The whole of the plates, frame, and upper cross-pieces, are thus beneath the surface of the electrolyte, which is indicated in Fig. 66 by the dotted line above the plate.

The plates are kept apart from each other by means of long inverted U-shaped pieces of ebonite, two or three of these separators being placed astride each positive, thus keeping the adjacent negatives from touching it. Fig. 68 shows the positive and

negative sections, with the supporting wooden frame and glass slabs ready for placing in the containing vessel. The latter, of best white moulded glass, is about 11 inches high and $7\frac{3}{4}$ inches wide—the varying widths for the three sizes being $4\frac{1}{2}$, $4\frac{5}{8}$, and $6\frac{5}{8}$ inches approximately. Each complete cell is then mounted in a pine-wood tray, the latter having a layer of sawdust on which the glass box beds nicely; and each tray, in its turn, is supported on three "mushroom" or glass fluid insulators, illustrated in Figs. 69 and 70. Each of these consists of two parts—a lower, which has an annular hollow, and an upper, which stands in

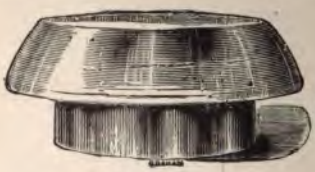


FIG. 69.
"MUSHROOM" INSULATOR.

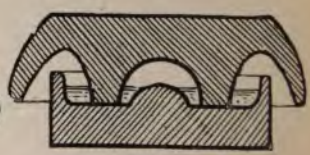


FIG. 70.
"MUSHROOM" INSULATOR—SECTION.

the hollow of the base. This hollow is filled with vaseline oil: any leakage from the cell must therefore pass over the whole surface of the glass insulator and also across the insulating oil.

Hart non-corrosive Terminal.—To connect cells together, the positive lug of one is brought to the negative lug of the next, and good metallic contact made between them. To secure such contact, however, is not an altogether simple matter. The internal resistance of the cells being very low indeed, it is important that no serious resistance shall be inserted in the connections. An ordinary metal screw terminal would be very convenient for coupling

and uncoupling, but there is great danger of setting up at the points of contact a series of resistances which in their total amount shall be very appreciable. Such a connection, too, if made of ordinary metal, will speedily be corroded by the acid fumes and spray. A solid burned joint is probably the best method, as is employed between the plates of a section and their bus-bar. To disconnect such a joint, however, is a serious matter.

For connecting their cells together the Hart Company use their patent non-corrosive terminal, illustrated in Fig. 66. This fitting is a taper bolt and nut, and the holes in the lugs are tapered also. The bolt, nut, lugs—and, indeed, the entire bus-bars—are of a special lead alloy which is entirely unaffected by the acid or acid fumes. In making a connection the surfaces of the lugs are brought together flat, and a "master-connector" used to draw them into good contact. This master-connector is a bolt and nut like the other, but is of gun-metal—the non-corrosive alloy being too soft to allow of any great strain being placed on the thread. When the lugs are thus drawn tightly together, the master-connector is withdrawn and the ordinary one substituted for it. The taper shape of the bolt ensures a good connection with the lugs by means of the contact with the inside of the hole—in addition to the contact between the flat faces of the lugs themselves. As the material is unaffected by the acid, it is unnecessary to paint it, or indeed any metallic part of the cells, with vaseline or other acid-proof compound. The Company claim for this fitting all the advantages—without any of the disadvantages—of a lead-burned joint.

Hart S-type Cells.—One of these is shown
Fig. 71. The main point of difference between t
type and that previously described is in the mann
of supporting the plates. The latter, shaped as
Fig. 66, and measuring approximately 4 ins. by 4 in
are furnished with extensions which form hooks

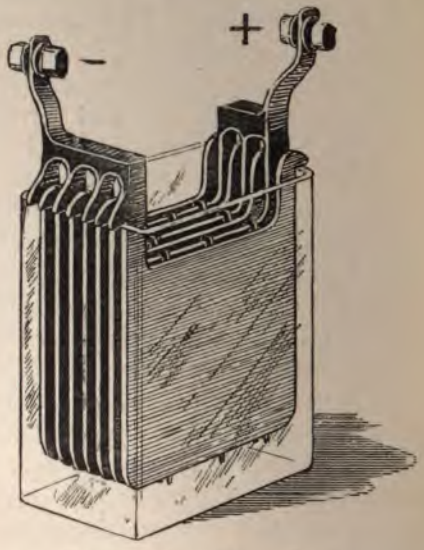


FIG. 71.—HART S-TYPE CELL.

their sides, and by means of these hooks the pl
are hung from the edges of the glass boxes th
selves. The wooden framework and glass-suppor
slabs are thus dispensed with. On each plate on
the lugs is extended and connected to the bus-
Five plates, mounted in a cell, form the 18, and s
plates the 27 ampere-hour size. The glass-con

ing boxes are about 6½ ins. high and 5 ins. long; the widths for the two sizes being 2⅛ ins. and 2⅜ ins. approximately.

These small cells do not have separate trays, but five or six are mounted in a single tray, which is supported on six insulators. Such a five-cell set is shown in Fig. 72.

For connecting together these small cells a slightly different fitting is used to that already described (see Fig. 66). The taper bolt of the latter is replaced by

FIG. 72.—HART S-TYPE CELLS, SET WITH TRAY.

a stud carrying a brass screw, which enters a rather long nut, the tapped hole in which is not drilled through. A couple of washers complete the fitting. When the connector is tightened up, the brass screw is entirely covered; and as all the rest of the fitting is of the non-corrosive alloy, no painting with acid-proof paint, etc., is necessary.

The following table gives the charging and discharging current and other details of the different cells:—

HART CELLS.

Capacity. Ampere-hours.	No. of Plates.	Charging Current. Amperes.	Maximum Discharging Current. Amperes.	Glass Boxes. Approximate Dimensions.		
				Height.	Length.	Width.
"S" type. Plates, 4″ × 4″ approx.						
18	5	1 to 2·6	2·6	6½″	5″	2⅛″
27	7	2 to 4	4	,,	,,	2⅞″
"T" type. Plates, 5½″ wide × 7½″ high, approx.						
45	5	6	7	11½″	7¾″	4¼″
72	7	9	11	,,	,,	5⅝″
90	9	12	15	,,	,,	6½″

Chloride Cells.—The positive of these cells are of the Planté type, and of rather novel construction. A plate of special lead mixture has cast in it as many large circular holes as it will contain. These holes, about an inch in diameter, are countersunk on both sides, and serve to contain "rosettes" of lead tape. The tape, or ribbon, about ¼ in. wide, is first "gimped" or corrugated at right angles to its length, and then rolled into small coils about 1 in. in diameter and inserted into the holes in the plate. The effect of the corrugations is, that between contiguous layers there is a series of interstices, thus exposing a large surface, and allowing the electrolyte free passage quite through the plate. The ribbon is simply plain lead, and the plate thus prepared is "formed" electrically. A complete pair of plates is illustrated in Fig. 73.

The construction of the negative plate was originally somewhat similar to that of the positive—"buttons" of lead chloride being carried by suitable

orations in a lead plate. By suitable processes e buttons were reduced to metallic lead of a very ngy character. It is to this employment of the oride of lead that the name of the cell—and that he makers, the Chloride Electrical Storage Com- y—is derived.

FIG. 73.—"CHLORIDE" POSITIVE PLATES.

The present negative is a pasted plate, known as "Exide" type. The grid consists of thin ver- al ribs, the edges of which are flush with the faces the plate. These ribs are connected by small izontal bars of triangular cross-section, the base the triangle being at the face of the plate. The s are not sufficiently wide to extend from side

to side of the plate, but are placed on both sides; those on the one side being "staggered" with those on the other. The active material between each pair of vertical ribs therefore forms a continuous pencil, of rectangular cross-section, extending from the top to the bottom of the plate.

An R G-type cell, with five plates, measuring $3\frac{3}{4}$ ins. by $4\frac{3}{8}$ ins., has a capacity of about $14\frac{1}{2}$ ampere-hours.

FIG. 74.—"CHLORIDE E_2T CELL.

Fig. 74 illustrates a small cell manufactured by this Company for a special telegraphic use. A negative and a positive plate are permanently united by a lead strip, in the same manner as the zinc and copper plates of an ordinary Daniell battery, are issued. The positive is placed in one cell and the negative in the next; the positive of a second pair being placed in the latter, and so on. The usual plan of

having a negative plate in excess of the number of the positives is, therefore, departed from—this being a two-plate cell. The plates measure $3\frac{3}{4}$ ins. by $4\frac{3}{8}$ ins., and the cell has a capacity of five ampere-hours. The plates are separated from each other by a sheet of perforated ebonite. Five of these small cells are mounted in a single tray—each alternate glass box having a pair of indiarubber rings round it to prevent surface leakage. These are plainly shown in the figure. This is the E_2T-type cell. The charging rate is about ·75 ampere, and the discharge rate can be as high as 1·5 amperes for three hours.

E.P.S. Cells.—The cell supplied by the Electrical Power Storage Company for telegraph purposes is their K or high-discharge type. The plates, both positive and negative, are of the pasted or Faure type, and measure approximately $9\frac{1}{2}$ ins. in length by $8\frac{3}{4}$ ins. in height.

The positive grid is a stout lead casting, consisting of a central plate with a series of horizontal ledges or "shelves" on both sides. The ledges are inclined upwards, so as to keep the paste in position. The finished plate is about $\frac{5}{16}$ in. thick. The negative grid is much lighter and only $\frac{3}{16}$ in. thick. The casting is really a set of thin vertical ribs $\frac{1}{4}$ in. apart, crossed by a similar set of horizontal ribs, also placed $\frac{1}{4}$ in. apart. We have thus a grating with square holes. As all the ribs are chamfered, the holes are largest at the surface of the plate (on both sides) and diminish at the centre. Hence the paste in each hole forms a pellet which is larger on its two faces than at its central region; it therefore cannot come out.

Fig. 75 shows a K-type cell. It actually has 33

plates, but the 23-plate cell is the largest in telegraphic use. Each of the negative plates is furnished with a couple of feet at the bottom corners, and these feet are burnt on to a pair of bus-bars running the whole length of the base of the cell. The two bars are united at the left, as can be seen in the figure, and the common strip is brought up out of the cell to

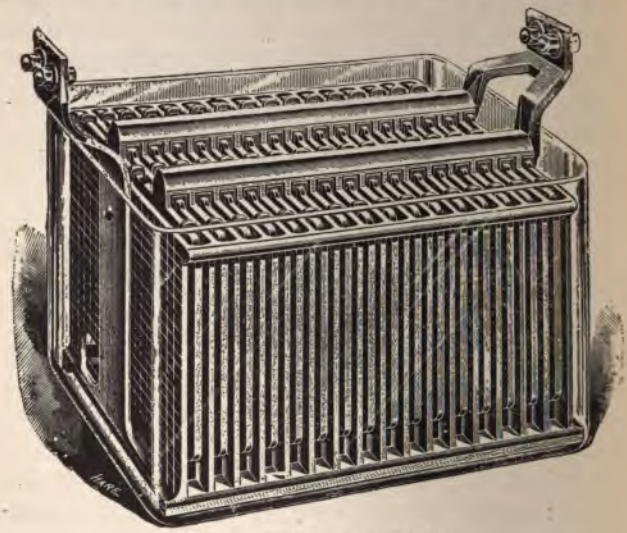


FIG. 75.—E.P.S. K-TYPE CELL.

form the negative terminal. The upper corners of the plates are also connected by other lead bars, one of which is visible in the illustration. The negative section thus forms a complete structure, the plates being connected together at the four corners of each, the whole standing on the bus-bars beneath.

The positive plates, slightly smaller than the nega-

tives, also have a pair of bus-bars to which they are connected and from which they hang. These are seen running across the top of the cell. They are united at the right to form the positive terminal. The positive section is thus supported, by means of its bus-bars, on the upper edges of the negative plates. On each of the latter, therefore, is placed a pair of ebonite saddles on which the positive bars rest.

The plates are kept apart from each other by ebonite forks, three of which are placed astride each positive plate in suitable notches in its upper edge.

The capacities of the three sizes in use, with 7, 15, and 23 plates, under normal rates of discharge, are 105, 245, and 385 ampere-hours.

CHAPTER IX.

EQUIPMENT OF BATTERY AND INSTRUMENT ROOMS.

THE standard installation for an office consists of 208 cells divided into two parts—main and local—the former serving the lines of greatest and medium length, and the latter the short lines and the local circuits of the relays—*i.e.*, actuating the sounders. They are, of course, used on the universal principle, but with the following modification. In universal working with primaries the whole battery is equally employed in supplying both the longest and the shortest lines, the resistance of the latter being brought up to that of the former by means of resistance coils. With secondaries, the whole battery is not equally in use, but taps are taken from various points so as to avoid the use of an unnecessarily high voltage, to be subsequently cut down by artificial resistance.

For the main battery 160, and for the local 48, Hart cells of suitable capacity are provided. The taps on the main set are arranged so as to give 40, 80, and 120 volts positive, and 40, 80, and 120 volts negative. The locals give 24 volts positive and 24 negative. Evidently these voltages do not require all the cells we have mentioned, and the diagram Fig. 76 will explain how the cells are allotted. The 80 on the negative (main) side are divided by the taps into

four sets of 20 cells each. Thus, with the last positive pole to earth the negative pole of this set gives 40 volts. The similar pole of the next set gives 80 volts negative, and that of the third 120 volts negative. The fourth set is idle for charging. On the positive side three similar voltages are obtained, and the fourth set is also available for charge. The 48 local cells are divided up into four sets of 12 cells each: one set to give 24 volts negative, a second to

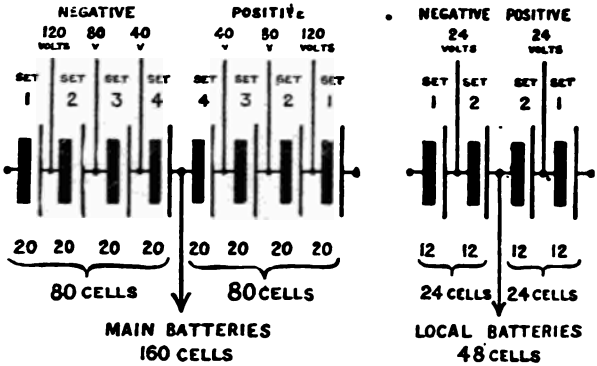


FIG. 76.

give 24 volts positive, and two for charge. Thus four sets, two of 20 cells each, and two of 12 each, are idle for charging purposes, whilst the others are at work or discharging.

Racks.—Fig. 77 shows how the cells are mounted on the racks. A framework of deal or pitch-pine, 4 ft. 3 ins. high by 2 ft. 3 ins. wide, and of varying length, supports the bearers, BB, on which the cells are placed, the whole being well covered with shellac varnish or other acid-proof covering. The bearers

for the T-type are 3 ins. by $2\frac{1}{2}$ ins., and the upper

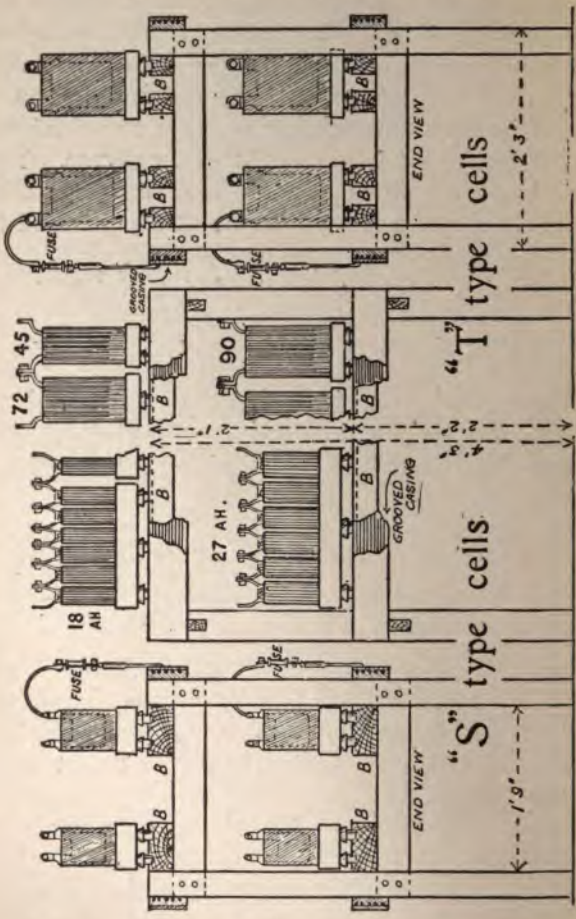


FIG. 77.

surface has a continuous groove cut in it in which the bases of the mushroom insulators rest. In the case

of the S-type cells the bearers are 6 ins. by 3 ins., and are placed with their greater dimension horizontal. A single bearer is then wide enough to take two grooves, and thus entirely support each tray. The racks have two tiers, and each tier carries two rows of cells. The comparative widths, etc., of the cells can be seen from this figure. The 18 and 27 ampere-hour trays are shown containing six cells: this is when the latter are used for local batteries—two trays then form a local "set." When used for mains they are mounted in slightly shorter trays containing five cells —four trays then make up a main set of 20. The leads from the positive and negative terminals of each set are taken, in the grooved casing shown, to the battery room cabinet, a 25-ampere "fibre-tube" fuse being included in each lead and placed between the terminal of the cell and the entrance of the cable into the casing.

Equalising of Load—Charging.—Now, considering the mains, when 120 volts are required, sets No. 2, 3, and 4 (positive or negative) are in use; when 80 volts are required Nos. 3 and 4 are engaged; and when 40 volts are in use set No. 4 only is at work. Thus set No. 2 will be worked least, No. 3 will be worked harder, and No. 4 hardest of all. Hence, if (say) all the positive portion of the battery, consisting of sets Nos. 2, 3, and 4, be charged together, No. 2 will be satisfied before No. 3, and both before No. 4. To avoid this, each set of 20 cells is shifted daily so as to occupy all four positions in turn. In the position shown in Fig. 76 No. 1 sets (positive and negative) are available for charge, and the positions of the others we have already pointed out. The next

day, taking the negative side, the whole four sets are

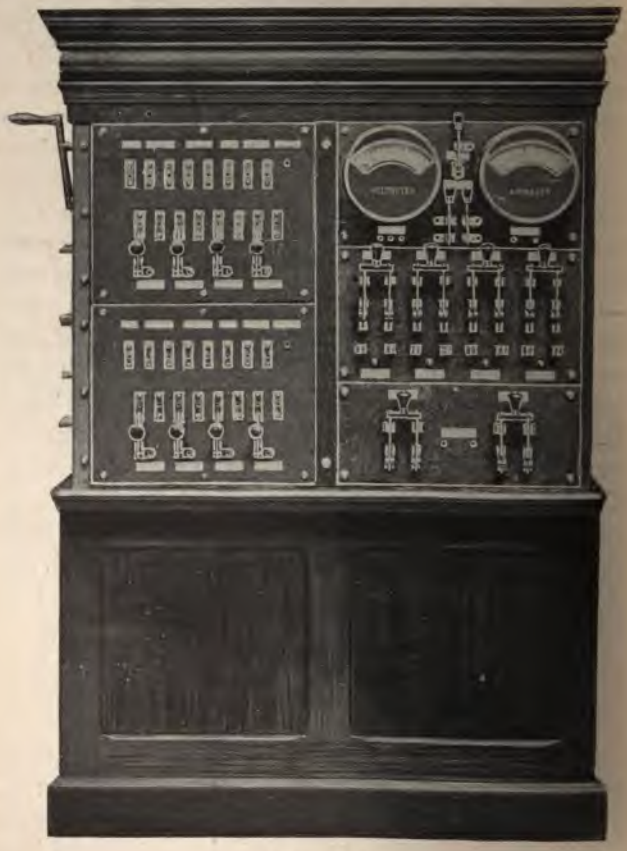


FIG. 78.

shifted one step to the left. This brings No. 2 into the charging position, No. 3 into that of lightest, No.

4 into that of medium, and No. 1 (charged the day

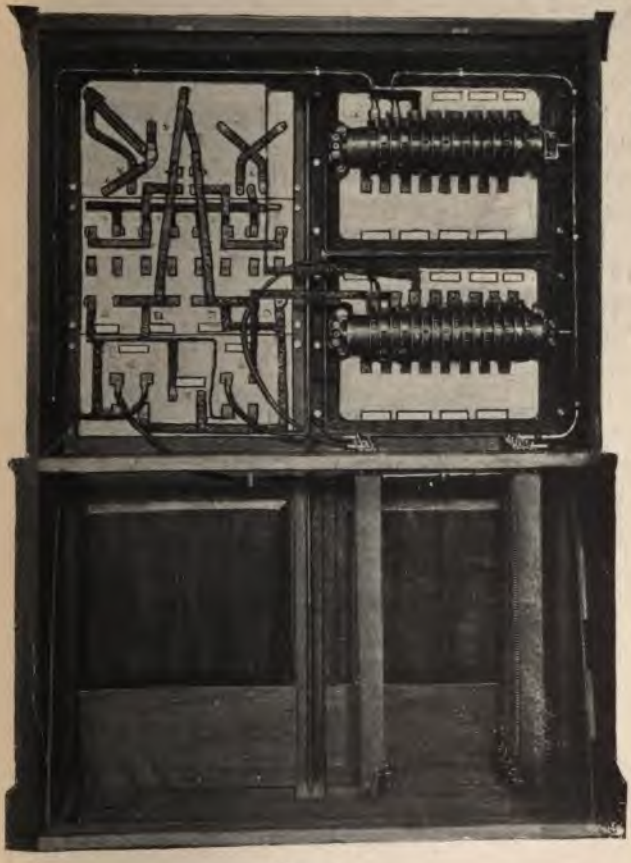


FIG. 79.

before) into the position of heaviest load. On the next and succeeding days the movement to the left is

continued, so that in the complete cycle each set is worked equally and then placed under charge. This daily shifting is effected by means of two 4-position rotary switches on the battery room cabinet, to be described later. In the case of the locals, since there is but one voltage (positive and negative) in use, this shifting is unnecessary. The changing of the two active with the two idle sets is effected daily by means of other switches on the cabinet.

For charging purposes the two idle local sets of 12 cells are placed in series with each other. This 24-cell battery, and the two idle main sets (20 cells each), are then placed in parallel. Obviously, such an arrangement as this would result in the two 20-cell sets getting more current than the 24-cell set. Hence each of the former has a resistance placed in series with it, so that the charging current in all three sets shall be the same—assuming that the local and main cells are of the same capacity. This grouping is all done by means of the switches on the cabinet, which latter will be described in the next section.

Battery Room Cabinet.—Fig. 78 is a front, and Fig. 79 a rear view of this with the back removed, and Fig. 80 gives the connections. On the left side of the cabinet are two tablets to which are brought the main sets: the four positives to the upper tablet, and the four negatives to the lower. Included in the circuit of each set is an ammeter switch. This is normally closed; but when it is desired to measure the current flowing through the lead of any particular voltage, the ammeter can be plugged across the switch by means of a pair of pegs connected by a flexible cord, and the switch then

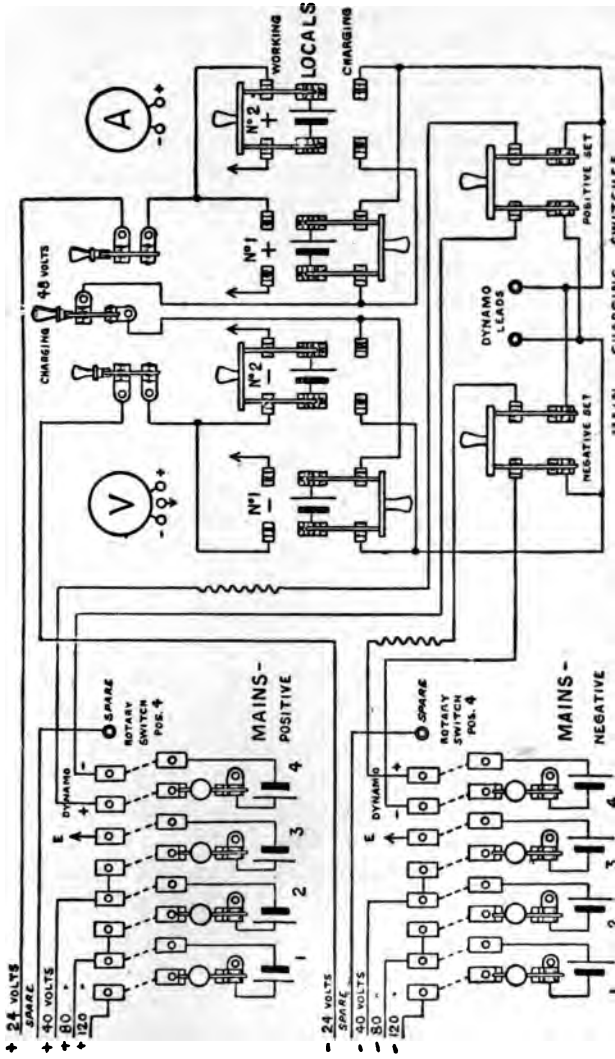

MAIN CHARGING SWITCHES
LOCALS
WORKING
CHARGING
48 VOLTS
DYNAMO LEADS
POSITIVE SET
NEGATIVE SET
MAINS-
POSITIVE
NEGATIVE
SPARE
ROTARY SWITCH POS. 4
DYNAMO
24 VOLTS
40 VOLTS
80
120

FIG. 80.

opened. These details can best be gathered from Figs. 80 and 83.

The right-hand side of the cabinet carries three tablets. On the centre one are mounted four double-pole two-position switches, which control the four 12-cell local sets. These are the "local switches." Each consists of two brass strips pivoted at one end and united at the other by a cross-bar of ebonite, which carries the handle. The contacts are formed of springy strips of phosphor-bronze, so bent that the two ends nearly meet. When, therefore, the switch lever is forced in between them, a good rubbing contact is made. Further, the fittings on which the levers are pivoted each carries a similar contact, so that the pivoting itself is not depended on for a connection. The battery leads are brought to the levers. When in the upper position each switch puts one pole of the battery to earth, and the other pole through to the instrument room, through an ammeter switch. Two sets—one positive and one negative—are thus put through. The other two switches are placed in the down position, and the two batteries attached to them are then ready for charge. It will be seen (Fig. 80) that the dynamo negative lead is joined permanently to the left-hand lower contacts of the two negative switches, and the dynamo positive lead to the right-hand lower contacts of the positive switches. The other two pairs of lower contacts are connected to the local charging switch. When the latter is closed the two idle batteries are put in series ready for charge.

The upper panel on the right-hand side carries this local charging switch—the two ammeter switches

before-mentioned—and a voltmeter and ammeter of the D'Arsonval type. The voltmeter reads from 0 to 150 volts, and the ammeter 0 to 50 amperes. In many cases the latter instrument has another shunt combined with the normal one; so that by using a third test-hole (not shown in Fig. 80) the sensibility of the ammeter is increased tenfold—a deflection of 25 indicating a current of 2·5 amperes.

The lower panel on this side carries the two main-charging switches. The two 20-cell main sets available for charge—one positive and one negative—are brought through the rotary switches to the points marked "dynamo" in Fig. 80. The positive leads are brought thence, each through a bare wire resistance, to the right-hand contacts of the charging switches, and the negative leads to the left-hand contacts. The levers themselves are permanently connected to the dynamo leads: hence the closing of these switches places the two sets in parallel and under charge.

Rotary Switches.—At the back of the left-hand tablets two barrel or rotary switches are mounted, seen on the right in Fig. 79. One is also shown separately in the upper part of Fig. 81. A wrought-iron cylinder or barrel, by means of suitable end-pieces, is carried in bearings, so as to be capable of rotation. On this is mounted a series of gun-metal rings with wide flanges. These are of two kinds: one a complete ring, and the other cut away so as to form four segments. These are illustrated on a larger scale in Fig. 82, showing front and side elevation. On the iron barrel complete rings and segmental ones alternate with each other, as in Fig. 81. The former are

lettered A, B, etc., to H, and, reckoning from the left, constitute the second, the fourth, sixth, etc., of the complete series. The incomplete or segmental rings form the first, third, etc., of the series. An end view of the switch is shown in Fig. 83, which is a section of (say) the upper left-hand tablet. The switch, etc., is

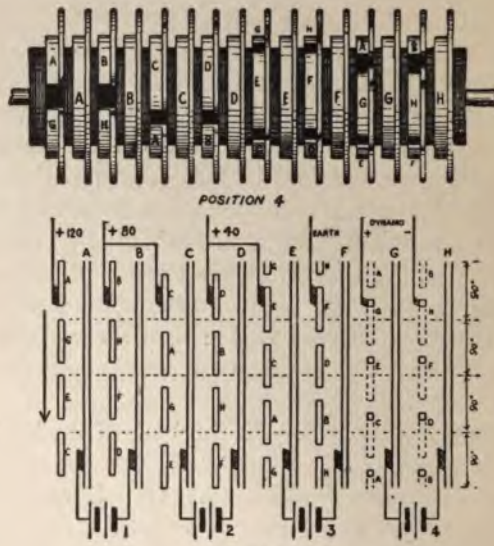


FIG. 81.

mounted at the back of this, and an ammeter switch, etc., on the front. The first segmental ring is, of course, fully seen—marked A, C, E, G, and in between the segments of this are seen portions of the full ring A. Now, in the position shown, the segment A is embraced by the brush *z*, and the complete ring A by the brush *q*. These brushes are of phosphor-bronze

and are double—that is, a set of blades presses on one side of the ring and another set presses on the other side, both sets uniting at the root of the fitting *z*. Similarly with *q*. Each ring and each set of segments is screwed to the wrought-iron barrel, as indicated in Fig. 82, but is insulated therefrom by a ring of fibre. The latter is shown black in this and other figures, whilst the inner shaded portion is the barrel itself. Now, each complete ring is connected to four segments—that is, to a single segment of each of four sets—by means of insulated wire running

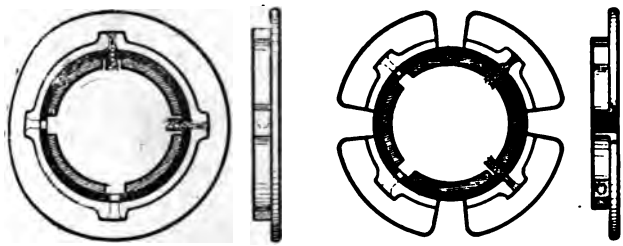


FIG. 82.

through the interior of the barrel. Thus, ring A is connected with a segment on the first, fifth, ninth, and thirteenth sets. B is likewise connected to a segment on the third, seventh, eleventh, and fifteenth sets. Hence, in the diagrams, wherever a segment and a ring bear similar letters, they are electrically connected.

Returning to Fig. 83, *s* is one of the upper series of rectangular brass pieces on the front of the positive main tablet, and is in metallic connection with the brush *z* and the connector *f*, to which the instrument room lead is soldered. The piece *p* is one of the

lower series of brass pieces on the same tablet. Alternate pieces on this row carry the upper contacts (test-holes) of the ammeter switches. The piece p is connected with the brush q. The fitting h is similarly

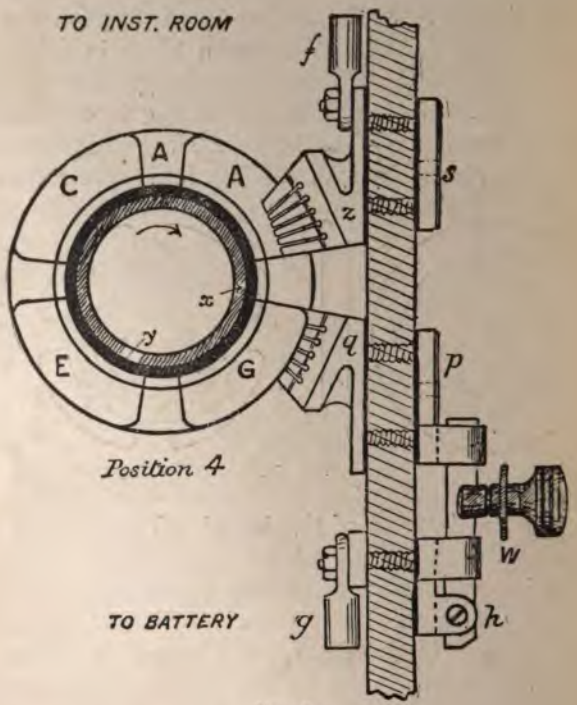


FIG. 83.

connected with g, and carries the lower contact of the ammeter switch W, the brass lever of which is also pivoted thereon. To the connector g the battery lead is soldered. With the switch in position 4, as

shown in Fig. 83, then, the battery being connected to g, the switch W puts it through by p to the brush q; thence to the complete ring A, and by the internal connections of the switch to segment marked A in the first set; thence by brush s and connector f to the instrument room lead. The lower part of Fig. 81 shows diagrammatically the segments and rings of the barrel laid out flat, so that the whole can be seen at a glance. The switch is in position 4. The arrow indicates the direction in which the barrel is turned, the brushes of course being stationary. Battery No. 1 is connected to the first pair of the lower row of brushes, and thus to rings A and B. The segments A and B on the first and third sets are in contact with the first pair of brushes on the upper row. The positive pole of set No. 1 thus serves as the 120-volt lead, and those of Nos. 2 and 3 as the 80 and 40-volt leads respectively; whilst No. 4 is under charge. Now, when the switch is moved forward one step, or 90° (to position 1), the segments C and D on the first and third sets come into contact with the first pair of upper brushes. Battery No. 2 being connected to rings C and D, its positive pole now serves as the 120-volt lead. Similarly with the others. The four positions of the switch are given in Fig. 84.

It will be seen from Fig. 81 that the segments of sets 1 and 3 are parallel with each other in the direction of the length of the barrel—that is, they break or make contact with their respective brushes at the same time: likewise those of sets 5 and 7, etc. But each *pair*, reckoning from the left, is slightly (20°) behind its neighbouring pair on the right. The result of this is that, in the movement of

three spirals can be connected up to give different values. Each spiral measures $\frac{3}{5}$ of an ohm—hence,

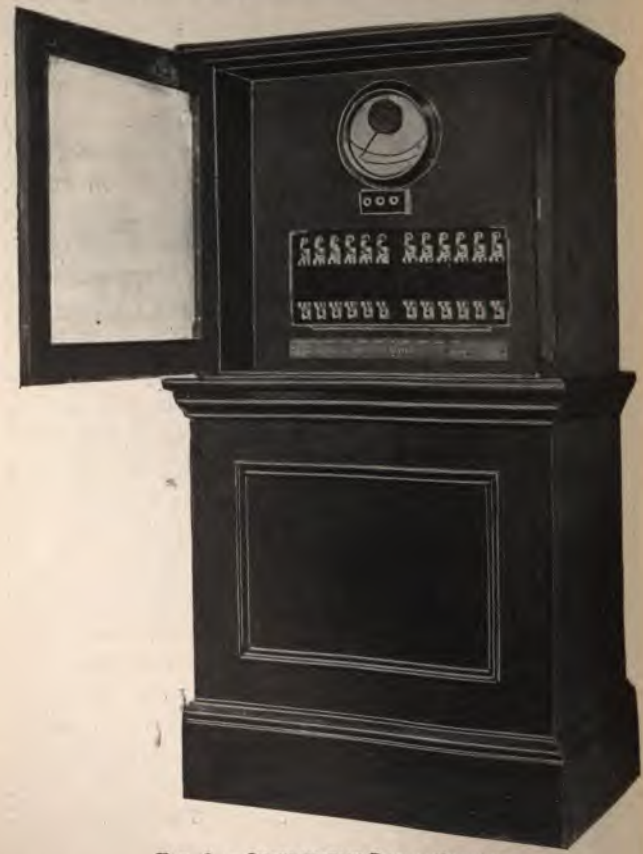


FIG. 85.—INSTRUMENT-ROOM CABINET.

by using a single one, we have this resistance: by using two in parallel, $\frac{1}{5}^{w}$, with two in series $1\frac{1}{5}^{w}$, and

so on. Spirals having other values are also employed where necessary. The bare conductor enables the heat developed to be freely radiated away.

Instrument-room Cabinet, or "Secondary Cell Main Distributing Cabinet."—This, illustrated in Fig. 85, corresponds with the "battery box" of the primary system. An ebonite tablet suitably mounted carries a series of twelve combined fuse-holders and test-holes with U-links. Each fuse-holder consists of a pair of phosphor bronze contacts, like those previously described, and in these a 5-ampere "fibre-tube" fuse is inserted. The brass piece carrying each contact is provided with a test-hole. There are two rows of these, and to the lower are brought the four negative, the four positive, and two spare leads from the battery-room cabinet. The upper row is simply mounted on the tablet. Immediately above this is a row of simple test-holes, to which are connected the distributing leads to the table cases, to be described later. With the fuse in position, the battery lead is thus brought to the upper contact springs. Connection between the latter and the test-hole above is made by a U-link, as shown in the figure. To disconnect the power from any lead it is therefore simply necessary to remove the U-link without touching the fuse. The voltages are arranged with the lowest (24) at the centre, the negative ranging upward to the left and the positive to the right. The eight leads and two spares thus require ten of the twelve fuse positions, the remaining two being spare. Above the fuse-tablet is fitted a D'Arsonval voltmeter with scale 20—140 volts, with a three test-hole tablet.

strip, whilst at the front is a square brass fitting, with a protruding nipple carrying a coarse thread. A

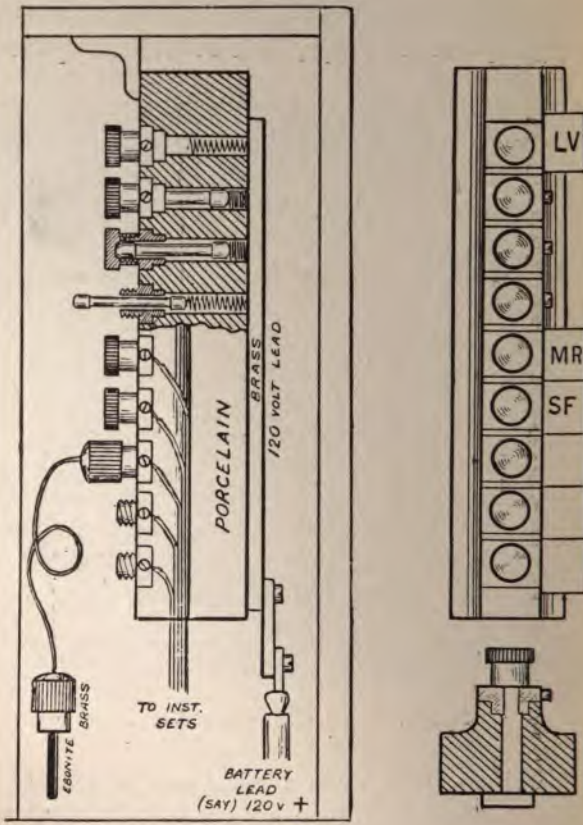


FIG. 88.

brass cap has a similar thread on its interior, and, normally, screws over the nipple. The latter and the

square portion also have a hole bored quite through them, so that when the cap is taken off a cylindrical hole exists from the end of the nipple to the back of the porcelain strip. At the bottom of this hole, as we have seen, is a spiral spring. The latter, even when fully distended, does not reach the metallic portion at the front of the hole—hence, whether the cap be on or off, there is no connection between the battery lead and the front fitting. The diameter of the hole, however, is such as to just admit a 1-ampere glass-tube fuse, and when one of these is inserted, and the cap screwed on the nipple, the fuse compresses the spiral spring and forms a connection between the battery lead and the front fitting. On the right-hand side (as seen from the front) of the square portion of the fitting is a screw, and this serves to clamp the end of the wire going to a particular instrument.

Each vertical row of these caps represents a particular voltage; and all instruments requiring this voltage have their leads connected to the screws on the right-hand side of this strip.

If it is desired to disconnect the battery lead from a particular instrument, this can be effected by simply unscrewing and taking off the cap and withdrawing the fuse.

To change the voltage on any set, two extra brass caps are provided and connected with each other by a flexible (conducting) cord. One of the caps is fitted with an ebonite pin. The ordinary cap is unscrewed from the normal voltage fitting, and the fuse withdrawn. Over this nipple the cap with the ebonite pin is then screwed. The pin forces down the spiral spring at the foot of the hole, preventing

contact with the battery lead. This cap is thus in connection with the instrument on which it is desired to bring a new voltage. A fuse is then inserted in a spare hole on the required voltage strip, and the cap at the other end of the flexible cord is then screwed over it, thus making the required battery connection.

Protective Resistances.—It will be seen that the current for any particular set, before reaching the sending key, has to pass through three fuses—the 25-ampere one on the battery rack, the 5-ampere one on the instrument-room cabinet, and the 1-ampere glass tube fuse on its particular table case. As a further precaution against short-circuit at any part of the system, an additional resistance coil is inserted between the table case and the key. It is placed on the instrument table, and is of such a value that if it were the only resistance in circuit the current shall not exceed half an ampere. Thus, for the 24-volt leads it is 50 ohms, and for the 40-volt 80 ohms. It is cased in metal so that the heat set up by an improperly-augmented current shall be freely radiated away, and shall do no harm beyond the coil itself. These metal-cased resistance coils are placed in the 24-volt leads when the latter are used as mains, but not when used as locals. The 80-volt and 120-volt leads have incandescent lamps (100 volt, 16-candle-power) similarly placed, mounted in suitable stands on the table.

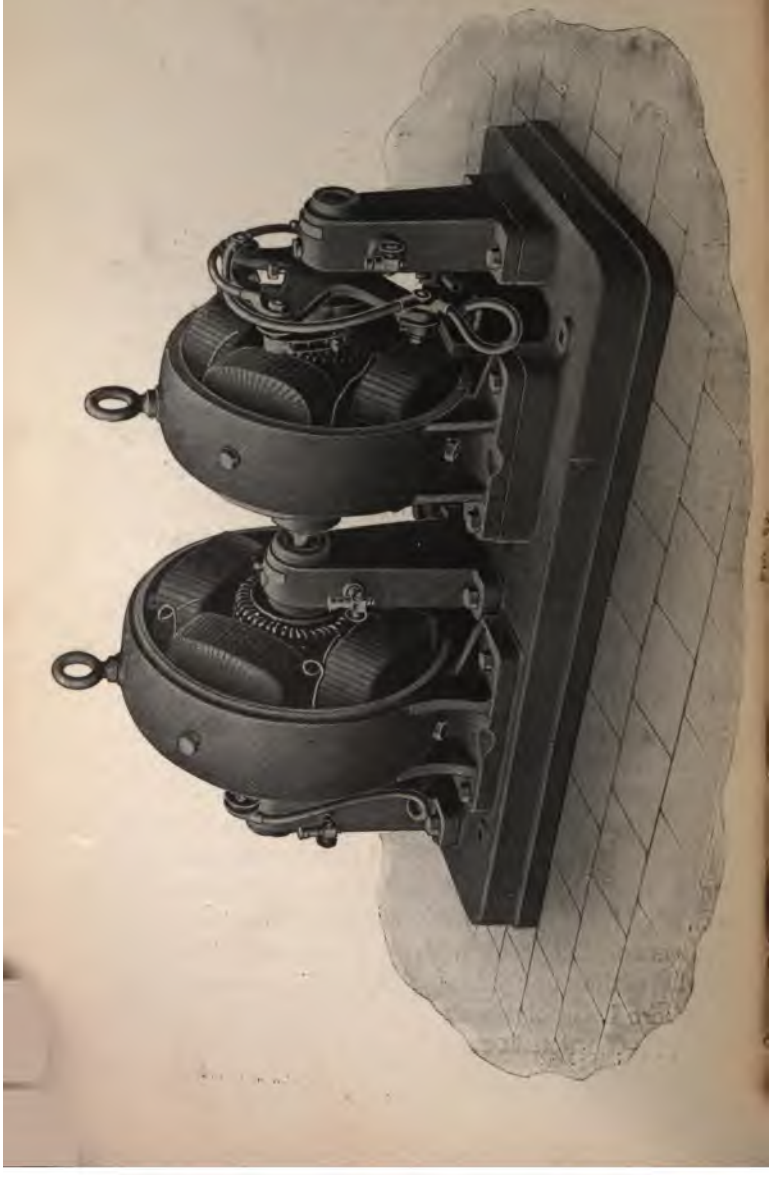
CHAPTER X.

CHARGING ARRANGEMENTS.

Means of Charging.—We have considered the cells themselves and how the current is taken through the battery and instrument-room cabinets and table cases to the instrument sets. We have also seen how, by the action of the rotary and charging switches on the former cabinet, the sets are selected for charge and are connected up to the charging leads. We now have to consider the means of charging, which may vary with the local conditions.

If the town has an electric supply, continuous current and of low voltage, say 100 volts, the cells can be charged direct from the public mains. This is the simplest arrangement of all. In the case (*a*) where no public supply is available, or (*b*) where one exists of too high a voltage or alternating, a dynamo is necessary and motive power to drive it. In the first case (*a*) of no public supply, a gas or oil engine may may be found convenient for driving purposes; in (*b*) an electric motor may be employed. The dynamo and the motor are then coupled rigidly together and form a motor-generator. There are three cases in which the latter combination is used: (i.) where the supply is continuous current, but above (say) 110 volts, (ii.) where the supply is single-phase alternating, and (iii.) where it is polyphase.

Motor-Generator.—We will now describe a com-



plete plant consisting of a motor-generator connected on the motor side with the mains of a direct-current supply of (say) 480 volts, together with the necessary adjuncts and accessories. The transformation is thus from high voltage direct to low voltage direct: the reason for the selection of this case for first consideration is that it is perhaps the most typical.

Such a motor-generator is illustrated in Fig. 89. It is constructed by the Lister Electric Manufacturing Co. (Messrs. Pinching & Walton). Both motor and dynamo are of the open type—4-pole shunt-wound, with drum armatures, and the combination runs at approximately 1,500 revolutions per minute.

This particular generator has a capacity of 1·5 kilowatts, giving about 23 amperes at a pressure of 65 volts. The resistance of the field-magnet coils (cold) is 22·5 ohms, and that of the armature 0·18 ohm. It will be remembered that the largest number of cells to be charged in series is the combination of two local sets—a battery of 24 cells, normally giving 48 volts. When the battery is becoming fully charged, the E.M.F. rises to about 2·5 volts per cell—hence the 24 when near the end of a charge will give 60 volts. The dynamo E.M.F. must of course always be above that of the battery. On the other hand, when the cells have run to the lowest permissible figure, the E.M.F. may fall to 1·9 per cell—hence the E.M.F. of the dynamo must be capable of variation, and the means adopted to secure this consist in the inclusion of a rheostat in the circuit of the shunt coils. The speed of running being practically constant, the E.M.F. developed is in direct proportion to the strength of the field. The latter depends on the

magnetising effect of the field-magnet coils. Hence if the rheostat is in a medium position—*i.e.*, with some resistance in curcuit—any reduction of this will result in an increased current through the field coils. This strengthening of the magnetic field will augment the E.M.F. of the armature. By increasing the resistance, of course, the reverse effects are obtained. The resistance in the rheostat is arranged in 35 steps, and has a total of 30 ohms. By this means the dynamo E.M.F. can be varied from 45 to 85 volts.

Two pairs of carbon brushes are employed, these being connected in parallel.

The motor, of course, is wound to suit the E.M.F. of the local supply. Where the latter is a "three-wire" system, and the pressure, as we have assumed, the P.D. between the middle or neutral wire and each of the outers, is 240 volts. All motors, however, as a rule, are connected across the outers, thus taking the full 480 volts. For this voltage the field resistance is 1,000 ohms, and that of the armature 2·8 ohms (cold). A single pair of brushes is used, making an angle of 90° with each other, the necessary cross-connection being made in the armature interior. The starter for this machine has a total resistance of 70 ohms, cut up into eight sections.

The two machines are mounted in line upon a common base plate, and are provided with three self-oiling bearings of phosphor bronze. The combined efficiency varies from 65 per cent. at full load to 50 per cent. at half load. The machine should carry any load between the limits of its design, with a fixed brush position, quite sparklessly.

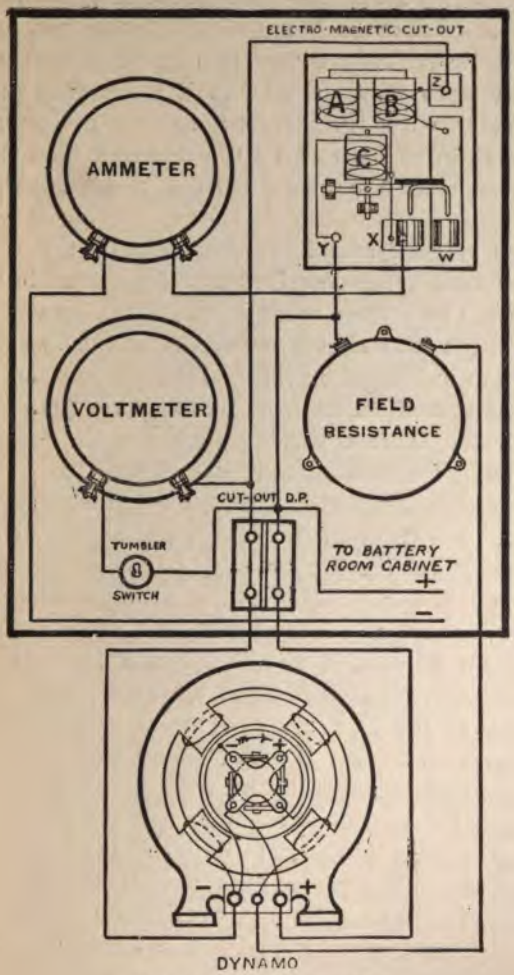


FIG. 90.—DYNAMO BOARD.

Dynamo Board.—For the mounting of the rheostat, cut-outs, etc., a board of teak, some 3 ft. by 2 ft., is provided. This, shown in Fig. 90 (together with the dynamo connections), carries the following: a voltmeter with tumbler switch, an ammeter, the rheostat in the circuit of the dynamo field-magnet coils, an electro-magnetic cut-out, and a double-pole fuse.

The voltmeter and ammeter are of the Stanley D'Arsonval type, described and illustrated in Chapter V. The former reads from zero to 80 volts, and is brought into circuit by means of the switch. It serves to indicate the E.M.F. at the dynamo terminals. The ammeter, reading from zero to 25 (or 40) amperes, shows the current passing to the cells. The field resistance we have already described.

Electro-magnetic Cut-out.—This piece of apparatus is illustrated in Fig. 91, and shown diagrammatically in the upper right-hand corner of the dynamo board. A horizontal arm, pivoted at its centre, carries at one end a copper fork, and at the other an adjustable weight. The latter end being the heavier, the fork is tilted upwards. Beneath the prongs of the fork are two metal cups containing mercury, and when the right-hand end of the arm descends the prongs dip into the mercury, and thus connect the two cups together. Fixed to the horizontal arm is a vertical limb of soft iron, whose upper extremity plays in a hollow coil, C, of fine insulated wire of 2,000 ohms resistance. Above this coil is placed, yoke uppermost, a horseshoe electromagnet, with its poles one on either side of the protruding limb of the movable system. The left-hand

coil, A, of the horseshoe is wound with fine wire to 400 ohms, whilst the right, B, has a few turns of stout conductor of negligeable resistance. The object of the lower coil is simply to polarize the soft-iron limb. Assume that it makes the upper end an N pole. The effect of the two coils on the horseshoe electro-magnet is to make the left-hand an N and the

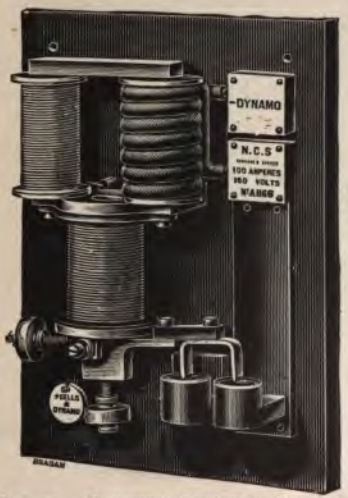


FIG. 91.—ELECTRO-MAGNETIC CUT-OUT

right an S, but the two windings are separate, and the circuit of the low resistance coil is incomplete until the fork connects the two mercury cups. During operations, current is always flowing through the lower coil, C, and also through coil A. When it attains a sufficient strength in the latter to overpower the effect of the weight, the soft-iron limb is repelled to the right. This causes the pivoted arm to push

the fork into the cups, and the circuit of coil B is thus completed. The latter, being of very low resistance, practically short-circuits the 400^{w} one; hence the current is largely increased, and the S pole formed by its action holds the lever firmly over to the right. Now if the dynamo E.M.F. should fall below that of the battery—by the slowing-down of the machine, or through the appearance of a fault—the cells will discharge through the dynamo, to the certain damage of the latter. This discharge current will be in the opposite direction to the charging one, excepting in coil C, where it will flow in the same direction as the charging current. The polarity of the movable arm will, therefore, be unchanged. Now if the reversal takes place slowly, the charging current will become less and less until the horseshoe magnet can no longer hold over the pivoted arm of the cut-out. The weighted end, therefore, falls, and withdraws the the fork from the mercury cups, and breaks the direct circuit. Further, if the reversal should take place suddenly—say owing to the sudden stoppage of the dynamo—the discharge current will reverse the polarity of the horseshoe magnet, and the vertical arm (its polarity being unchanged) will move to the left, and thus break the circuit. The effects of the action of the cut-out can best be seen in Fig. 98.

A dynamo used for charging purposes is invariably shunt-wound. The reason for this is that, should the reverse current from the cells reach the machine, the polarity of the field-magnets will be unaltered. In the case of a series-wound machine the polarity would be reversed, and on making a fresh start the dynamo would send its current in the reverse direction.

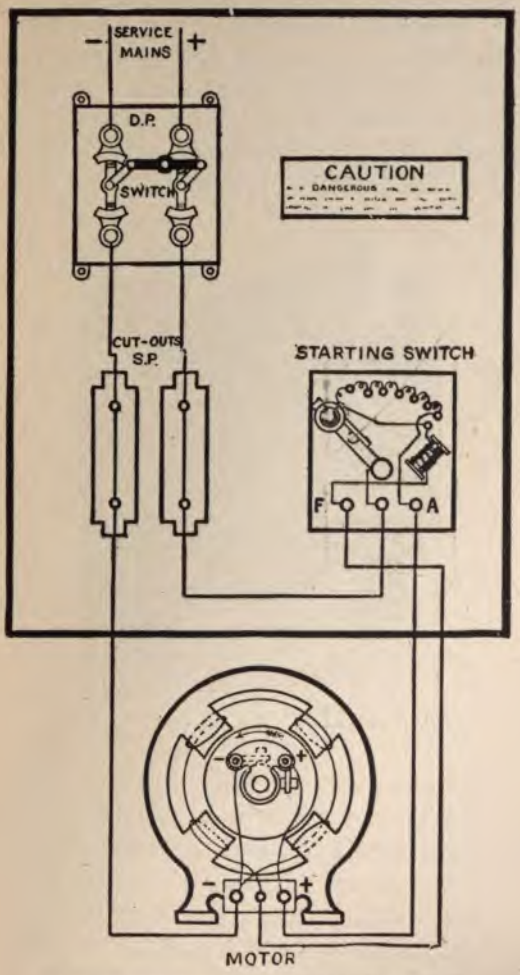


FIG. 92.—MOTOR BOARD—DIRECT-CURRENT.

Motor Board (direct-current).—This, with the motor connections, is shown in Fig. 92. The leads from the mains are brought first to a fuse installed by the supply company, thence through a meter to a double-pole switch on the board. This, illustrated in Figs. 93 and 94, is the "Acme" pattern of Messrs. E. F. Moy, Ltd., and is provided with an iron case.

FIG. 93.—"ACME" DOUBLE-POLE SWITCH

The first illustration shows the switch complete; the second with the cover removed. From this the leads pass through a pair of cut-outs (fuses), the negative going to the motor and the positive to the lever of the starting switch. When the latter is moved over to the right the current splits, part going through the starting resistance to terminal A and thence through the armature, the other part going through the small

electro-magnet to terminal F and then to the field-magnets. Both parts reunite at the negative terminal of the motor. The lever is moved over slowly as the motor gains speed, and step after step of the resistance is cut out from the armature circuit and thrown into that of the field. On reaching the right-hand limit the lever is permanently held over by the electro-magnet, and the starting resistance is short-circuited.

FIG. 94.—"ACME" D.P. SWITCH, WITH COVER REMOVED.

The function of this "'no voltage' release" is fully explained in Chapter II. in connection with Fig. 29.

Motor Board (single-phase alternating).—Fig. 95 shows the arrangement of the motor-board when the supply current is alternating, single-phase. The leads from the mains, after passing through the double-pole switch and cut-outs, are led—one to terminal M of the motor, and the other to the centre

terminal of the two-position starting switch. The ends of the starting resistance are brought to the

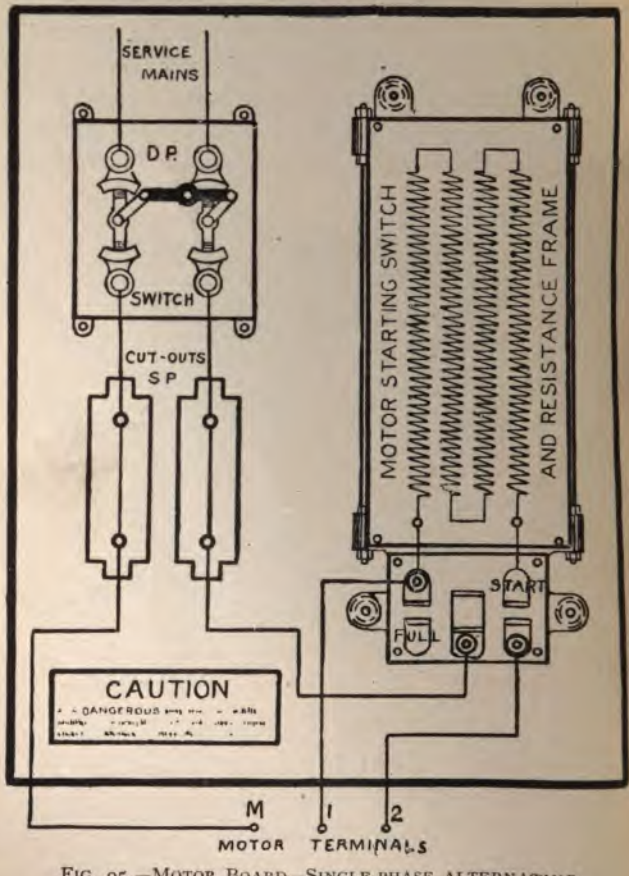


FIG. 95.—MOTOR BOARD—SINGLE-PHASE ALTERNATING.

"full" and "start" positions of the switch, the latter being also connected to terminals 1 and 2 of the

motor. Between M and 2 is the motor main winding, and between M and 1 is placed an auxiliary winding for starting purposes. In starting, the switch is turned to the right, and the two windings are then placed in parallel, the auxiliary winding having the inductive resistance included in its circuit. The current passing through the latter is retarded or put

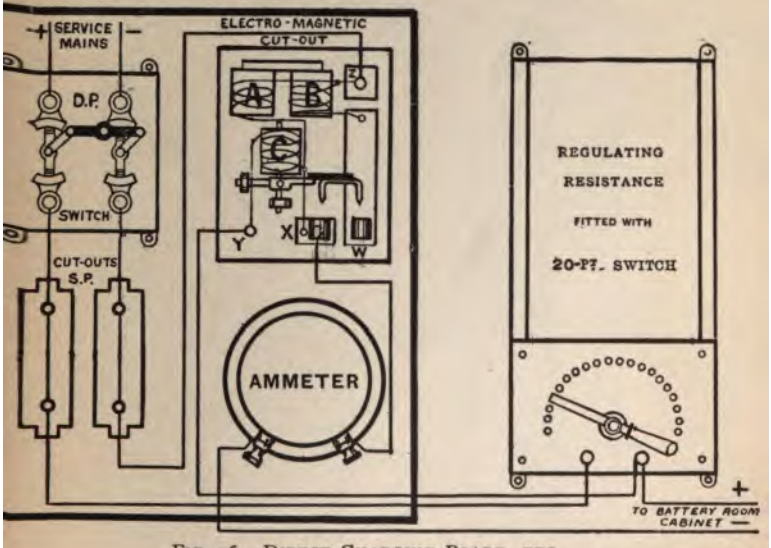


FIG. 96.—DIRECT CHARGING BOARD, ETC.

out of phase with that in the main winding, so as to produce an artificial two-phase arrangement, by which the motor is enabled to start. After this is effected the switch is turned to the "full" position, and the auxiliary winding cut out. This device is necessary because the single-phase induction motor is not self-starting. See Chapter III.

Polyphase Motor.—Where the supply is two or three-phase alternating, the motors are self-starting, and small machines are often connected directly to

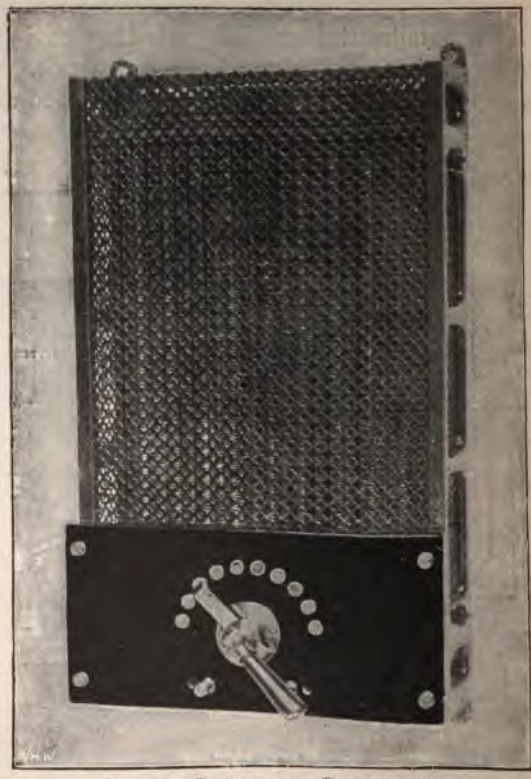


FIG. 97.—REGULATING RESISTANCE.

the mains by the closing of the main switch—no starting device being necessary. For 3-wire two and three-phase this switch simply makes three contacts simultaneously.

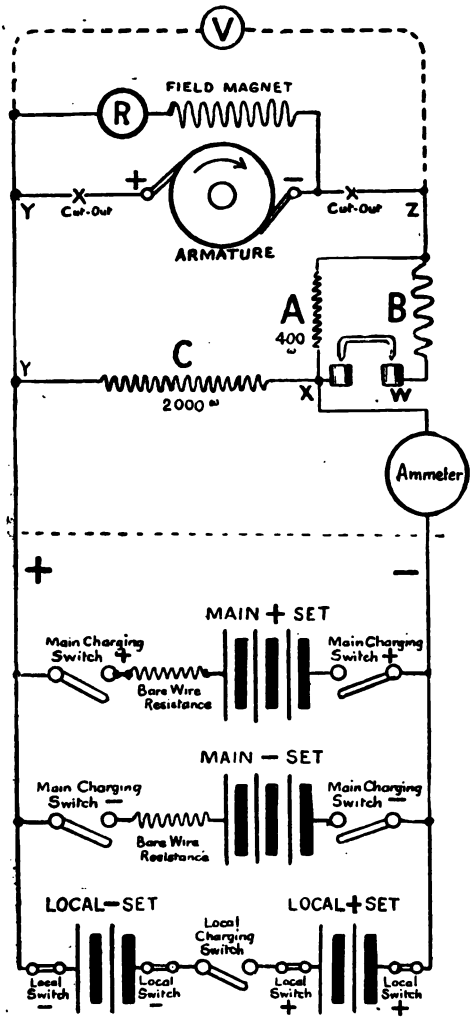


FIG. 98.—CHARGING CIRCUIT

straight and equidistant from each other. After placing the ebonite forks astride the positives, the sections have to be stood on the glass sheets carried by the wooden frames. We have ensured a good seating for the latter in the glass cell. It should, therefore, be taken out, the section lifted by the two bus-bars (positive and negative) and placed with the lugs of the plates resting on the edges of the glass slabs. The wooden cross-pieces can now be put on the uprights, and the complete frame, with its glass sheets, should be tied to the section with string, so that when the section is lifted by the bus-bars the frame is lifted with it. The parts of the cell, except the containing vessel, are now assembled (as in Fig. 68), and the combination may be lifted into its glass box which has already been stood in the tray. The string being then untied and removed, the cell is complete and ready for placing on the rack.

Setting up S-type Cells.—The initial procedure is as already detailed. The sections of this type, however, have no supporting wood frame or glass sheets, but are hung from the sides of the glass box itself. Each wooden tray, too, carries five or six cells. Hence each tray should be stood on the bench as before, an even layer of sawdust placed in it, and the glass boxes stood thereon. The sections should then be lifted by the bus-bars and placed in the boxes with the projecting lugs of each plate resting on the edges of the box. Care must be taken that all the plates hang quite vertically and are central in the boxes, that is, with their edges in alignment and a clearance between the edges and the inside of the glass cells. Two ebonite forks should be placed

astride each positive plate, except the outer ones, which should each have three.

The outer negative at one side should go quite up to the side of the cell. There will then be a small space between the other outer negative and the glass. In this space are placed vertically two $\frac{3}{8}$-in. corrugated lead strips, which are sent with the cells, about $2\frac{3}{8}$ ins. apart and in line with the forks. Owing to the tapering of the boxes, the space will be less at the bottom than at the top, and it will be necessary to flatten out the strips a little towards the bottom.

The six cells can now be placed in their proper tray and connected together, and the whole is then ready to be put in position on the rack.

Mounting on Racks.—The mushroom insulators, duly filled with oil, should be placed in the shallow grooves cut for their reception in the bearers of the racks and the cells, complete with their trays, stood on the insulators. With each T-type cell three of the latter are used, say, two at the back and one in front. The next tray should have one insulator at the back and two in front, and so on alternately. With the S-type cells each tray has its six insulators equally divided between back and front. The cells should be placed so that the plates lie at right angles to the length of the racks, and a space of about an inch left between each glass box and its neighbour, or about half an inch between the trays. The contact surfaces of the lead lugs having been carefully cleaned and placed together and the connectors screwed up, the cells are now ready for the acid solution: this, however, must not on any account be put in until all is ready for charging.

First run of Dynamo.—We now assume that the motor generator is properly erected, that the power (motor) and dynamo boards are fixed and wired, that the battery-room cabinet is set up and the cells all connected thereto, but no acid yet placed in them. Further, we assume that all connections are made between the supply mains, power board, motor, dynamo, dynamo board, and battery-room cabinet. Everything, in short, is ready for a start, except that the acid is not yet put in the cells.

We now have to see whether the machine is prepared to do its work. First, make sure that the local and the two main-charging switches on the battery-room cabinet are open, that the lever of the motor starting-switch is in its disconnected position, and that the dynamo rheostat on the power board has all its resistance in circuit, *i.e.*, its handle turned as far as it will go in the direction for "lowering voltage." The voltmeter on this board should be brought permanently into circuit.

Starting Motor.—Close the main double-pole switch on the motor board, and advance starting-switch lever to first contact stud, and then to second and third, resting on each for a slight interval as the motor, after starting, gets up speed. As the speed further increases, the lever may be moved from stud to stud, with a pause on each, until it is in the proper position for running, full over to the right, where it will be held by the attraction of the electro-magnet. The motor is now running and driving the dynamo. As the whole of the field resistance is in circuit, the voltmeter will indicate a low E.M.F. The resistance been gradually cut out, the E.M.F. should rise to its

maximum. This, of course, is assuming that all is in order, and that the dynamo excites up properly.

When it is desired to stop the machine (the cells being first cut off by the opening of charging switches), this should always done by opening the main double-pole switch, never by attempting to move the starting-switch lever. When the main switch is opened, the starting-switch is released automatically, and no arc-ing takes place.

Dynamo failing to excite.—When starting a dynamo we always depend on the presence of a certain amount of residual magnetism, which is a result of the last run. This sets up a weak field, and in cutting this a feeble current is generated in the armature. This current, passing round the shunt coils, augments the magnetism of the cores and provides a stronger field, to be cut by the armature. This mutual building-up goes on until the dynamo is properly excited.

The machine, before delivery, has of course been put through a trial run and thoroughly tested at the manufacturer's works. The jarring and jolting of a railway journey, however, are liable to deprive it entirely of its residual magnetism: hence, when the machine is erected and started, it will not excite. The remedy is a simple one. Half-a-dozen primary cells, in series, should be connected to the field-magnet coils for a few minutes, care being taken to connect-up in the right direction—the positive pole of battery to the positive terminal of the machine—so that the battery-current shall pass through the shunt coils in the same direction as the current from the armature would do. As the armature coils are in

parallel with the shunt, it is advisable to lift the brushes while the battery is on. This being done with no fault existing, after running for a short time the dynamo will give its proper E.M.F.

Checking Connections.—It is, of course, a matter of the greatest importance that the positive pole of the generator should be brought to the positive terminal of the cells it is desired to charge. The proper running of the leads can easily be checked as far as the dynamo board by means of the voltmeter mounted there. If the leads are by accident crossed, the pointer of the instrument will be held dead against the zero stop, and no reading can be obtained. Further, if the voltmeter on the battery-room cabinet be pegged into the test-holes labelled "dynamo leads" between the two main charging switches, this instrument will check the proper joining-up of the leads to the cabinet. The full deflection will not be obtained on this voltmeter, as the 400^{w} coil of the automatic cut-out is included in this circuit.

Initial Charging of Cells.—We have now proved the dynamo—that it is ready to do its work. To give the cells their first charge we must be prepared to run the dynamo uninterruptedly for a somewhat lengthy period—36 to 40 hours.

As the machine is designed to charge only 64 (40 main and 24 local) of the 208 cells at once, we cannot charge the whole at one operation. One plan is to follow the normal working arrangement, *i.e.*, to take for a single operation a positive set of 20 cells, a similar negative set, and a combined local set of 24 cells, and to charge these in parallel. For the second operation the rotary switches are turned to the next

position, giving the next two main sets; the other pair of local sets is brought on by means of the local switches: these three sets are then charged in parallel. For the third and fourth operations the necessary movements of the barrel switches are made, but in these two latter cases we have only the main sets to charge. It will be seen that as each operation lasts for 36 hours, the whole series will occupy fully a week's time, day and night, which lengthy period it is desirable to abridge.

This can be accomplished by charging all the positive sets in parallel, then all the negative and then the locals, thus reducing the operations to three. To do this, some alteration of connections are necessary at the battery-room cabinet. With either rotary switch in, say, position four, No. 4 main set is connected to the dynamo leads. To put the other three sets in parallel with this, their ammeter switches must be opened, and the connections made by pegs and cords on the front of the cabinet. There are sufficient test-holes to allow of this. The bare wire resistance will require to be reduced to its minimum or cut out entirely. In charging one combined set, the charging switch (positive, negative, or local) of that set only is to be closed, those of the other two being carefully kept open.

Taking as an example a case where the first plan is adopted, and where the mains and locals are of the same capacity, say, 45-ampere hours, the charging current for these (from the table in Chapter VIII.) is 6 amperes; and as there are three rows in parallel we shall require a total current of 18 amperes. The local set of 24 cells will need the highest voltage—

something over 50 volts. But the 20-cell sets do not require so much; hence the excess must be cut down by means of the bare wire resistance. We really want about 42 volts, and must, therefore, absorb 50—42=8 volts. The current being 6 amperes, the required resistance is $\frac{8}{6} = 1\frac{1}{3}$ ohms, in series with each main set. The resistances must accordingly be set at this figure.

When all is ready for commencing the first charge —and not till then—the acid solution should be poured into the cells of those sets which have been selected for charge, but not into the others. Sufficient should be put in to cover the plates by at least half an inch. The proper specific gravity of the solution is 1,190, but it will fall below this figure when first put into the cells, and may not commence to rise for a considerable time after charging has started.

All switches being open, the maximum resistance inserted in the field rheostat and the motor-generator being well supplied with oil, the motor can be started in the manner before detailed. When the machine is running steadily the generator E.M.F. should be adjusted by means of the rheostat until the voltmeter indicates an excess over the batteries to be charged (this will be in excess of 48 where locals and mains are grouped). The charging switches can then be closed. Only a small current of course can pass until the electromagnetic cut-out cuts in, as before this is done the 400^{w} coil is in the charging circuit. If the apparatus does not cut in, the dynamo E.M.F. must be raised until it does cut in—it must *not* be actuated by hand. After the cut-out has acted and current flows to the cells, the dynamo E.M.F. can be adjusted to give the

exact current required. It may be added that if reference be made to the ammeter on the power board after the closing of each charging switch in succession, it can easily be seen whether the current increases by the proper amount as each fresh set of cells is added.

The dynamo should on no account be stopped for the first twelve hours. As the charging proceeds the specific gravity of the electrolyte will rise, and towards the end of the 36–40 hours gas should be freely liberated from both positive and negative plates, and the specific gravity and voltage cease to rise any further. The values of the latter should be 1205–1208, and about 2·5 volts. If at the end of the first charge the sp. gr. rises above 1210, pure distilled water must be added to reduce it to 1205–1208. This should be added whilst the plates are gassing, as the gas agitates the acid and ensures thorough mixture. If addition is made when liquid is quiescent, the water, being lighter than the electrolyte, tends to remain at the top.

On the completion of charge the charging switches must first be opened and then the dynamo stopped—never the reverse, or the safety devices may fail and a disastrous burn-out result.

CHAPTER XII.

Care of Secondary Cells.

THE secret of the successful maintenance of a secondary battery is proper treatment and purity of materials. A battery should always be kept fully charged—that is, as soon as the normal discharge has been drawn off, re-charging should commence. The cells should never be allowed to stand idle in a discharged state, or sulphating will surely follow. The charging current should be kept well within the proper limits. A moderate rate, extending over a longer time, is always to be preferred to a larger current and shorter time. A battery subjected to too high a charging current may gas freely before its capacity is really satisfied—in other words, energy is being poured into it at a greater rate than the battery is capable of absorbing. Thus it is always wasteful, and if sufficiently above the normal may result in blistering of the active material, formation of growths on the plates, and forcing out of the paste; all these being due to the combined action of the gases evolved, and to the expansion of the material. It may indeed be found economical and judicious to reduce the charging current considerably when nearing the end of a charge. The discharge current, too, should always be well within the specified limits, and never persisted in to exhaustion. Of course, in practice, cells

have to stand certain abnormal discharges and would be useless if no margin were available for eventualities; but every care should be exercised to avoid throwing a strain upon them, and drawing upon this reserve.

The capacity of the cells chosen for telegraphic purposes is considerably in excess of requirements, so as to furnish the necessary margin in case of any breakdown of charging-plant, etc. Hence, under these favourable circumstances the cells should always be in the very best of condition. When fully charged the positive plates should be of a reddish-brown or chocolate colour, and the negatives a bluish-grey. Regular and systematic tests of the voltage and density of each individual cell should be taken. Slight variations from the normal will, of course, be unavoidable; but the conditions being so favourable, a high standard should be kept up, and variations which would be passed over in a battery subjected to great wear and tear should be carefully enquired into.

At the end of the first few charges, the current being kept on until the specific gravity ceases to rise, slight differences in the density of different cells may show themselves. It may then be necessary to level the cells by withdrawing some solution from those of higher density and replacing with distilled water. After this, with the exception of "topping up," *i.e.*, adding water to make good evaporation losses, there must be no further interference with the electrolyte, as its variations are a gauge of the condition of the cells.

As to the materials used. The acid solution is

supplied with the cells, so that the initial stage is safe. The operation then needing watchfulness is the introduction of the water in topping up, as assuming cleanliness in the battery room, this is the only way in which impurities can be introduced. It should be borne in mind that, although the impurities brought in at a single operation may be almost inappreciable, yet the accumulation in, say a year's time, may be very considerable. For this purpose, then, only pure distilled water is suitable. Rain-water, when collected off a non-metallic roof, is sometimes used; but this is a fertile source of the introduction of ammonia and ammonium compounds. These, in considerable quantity, are decidedly harmful to a battery. This should be added at the end of a charge whilst the plates are "gassing." To do this properly, the following procedure should be adopted. Whilst the gases are pouring off no hydrometer reading is practicable; hence, before attempting to take it, the electrolyte must be allowed to become quiescent. If the reading then shows too high a gravity, needing dilution, the dynamo should be run again for a short time—in order that gassing may again be set up—and the water then added, the agitation of the liquid ensuring thorough mixture. If it be added when the electrolyte is perfectly steady it is liable to remain at the top—being lighter than the dilute acid. The solution should always be at least half an inch above the top of the plates, as if any portion of the latter be exposed, the covered and uncovered portions are subject to unequal expansion and contraction.

Hydrometer and voltage readings of every cell

should be systematically taken. These furnish a key to what is taking place in the battery, and, by careful observation, a developing fault may be removed at an early stage. The specific gravity should rise to 1200–1210 at the conclusion of charge, and discharge should never be persisted in after it has fallen to 1170. With the generous margin allowed in telegraphic practice, however, the latter limit will rarely, if ever, be reached. The voltage should rise to about 2·5 on charge; and the lowest permissible value to which it may fall is about 1·85. The proper time for taking the E.M.F. and gravity tests is just after charge and discharge—in the latter test as soon as the liquid becomes quiet.

Sulphating is generally the result of under-charge or over-discharge. When a whole battery is thus affected, it points to very bad usage. However, slight sulphating may occur in a cell here and there, the rest of the cells being perfectly normal. Such sulphating is the product of local action and short circuit, and shows itself by high voltage on the passage of the charging current—due to the drop in the cell—low voltage on discharge, and low density of electrolyte. Local action is due to the presence of foreign metals in the solution; hence the need for the greatest care in securing purity of acid and water. Short circuits may be formed by foreign substances finding their way into the cell, and bridging over the plates; by bad buckling, or by dislodged active material. If the short circuit be of low resistance, the resulting current will be excessive, and a fault will soon be apparent. If, however, it be of high resistance, its action will be slow, and, perhaps,

not manifest itself for some time—the cell simply refusing to show up so well in test as the others. The presence of such a short circuit in a cell would result, after discharge, in an E.M.F. lower than that of its neighbours. In addition, the density will be lower and cannot be brought up to that of the others, even by protracted charging. The remedy, after removing the short circuit, is to charge the affected cell until it is brought up to normal. To do this, it should be kept in circuit for charge, and disconnected when the battery is discharging—the screwed connections of the cells allowing this, and the substitution of another to be effected with comparative ease.

CHAPTER XIII.

USE OF THE GAS-ENGINE.

IN cases where no public service of electricity is available, and a gas supply exists, a gas-engine is a convenient source of power for driving a charging dynamo.

The first of the two accompanying figures illustrates one of the National Company's smaller engines, and the second gives a diagrammatic view of the end and a side section.

A jet of coal-gas burns quietly in the atmosphere: that is, continuous gentle combustion goes on at the nipple of the burner, where the temperature is sufficient to cause the combination of the oxygen of the air with the constituents of the gas. But if a closed space be filled with a mixture of gas and air and a light applied, the combination, instead of going on at a single point, extends over the whole space enclosing the mixture: in other words, the combustion of the whole volume takes place practically instantaneously. Combustion under these circumstances becomes explosive, and the resulting gases, enormously expanded by the heat, endanger the safety of the containing walls. The greater the pressure—or the larger the amount of gases compressed into the same space—the greater the violence of the explosion, and the larger the amount of resultant gases thus suddenly freed.

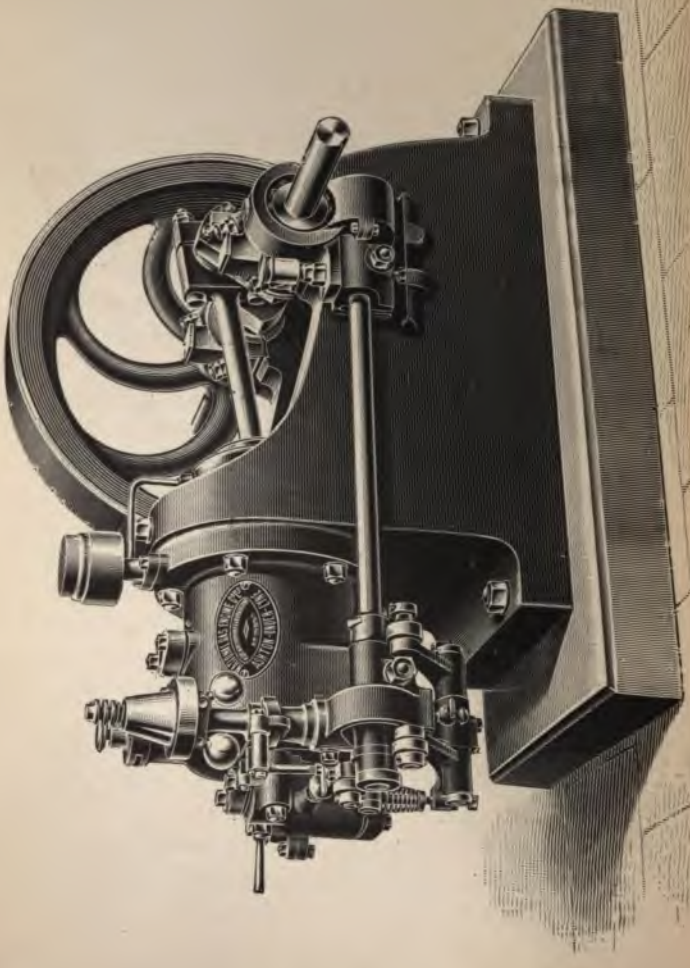


FIG. 99.—NATIONAL COMPANY'S "J" TYPE GAS-ENGINE.

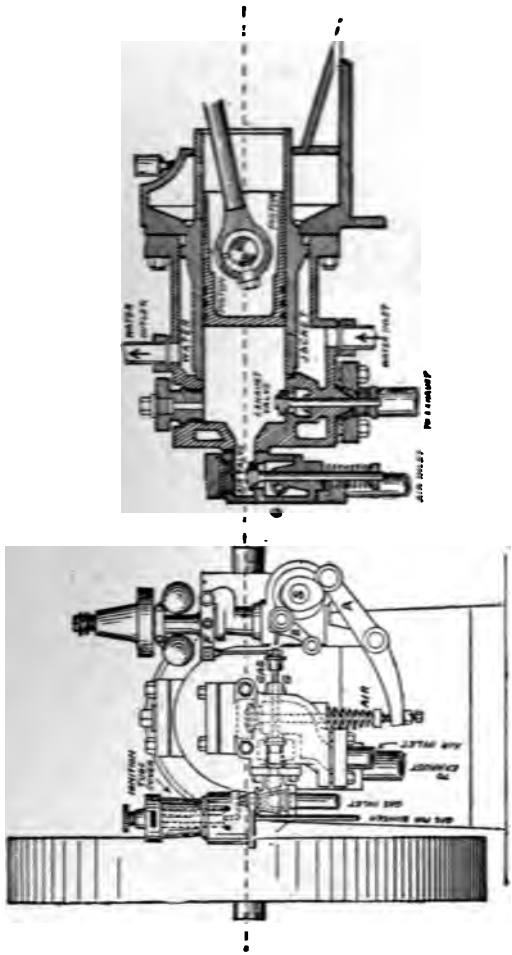


FIG. 160. END AND SIDE SECTION.

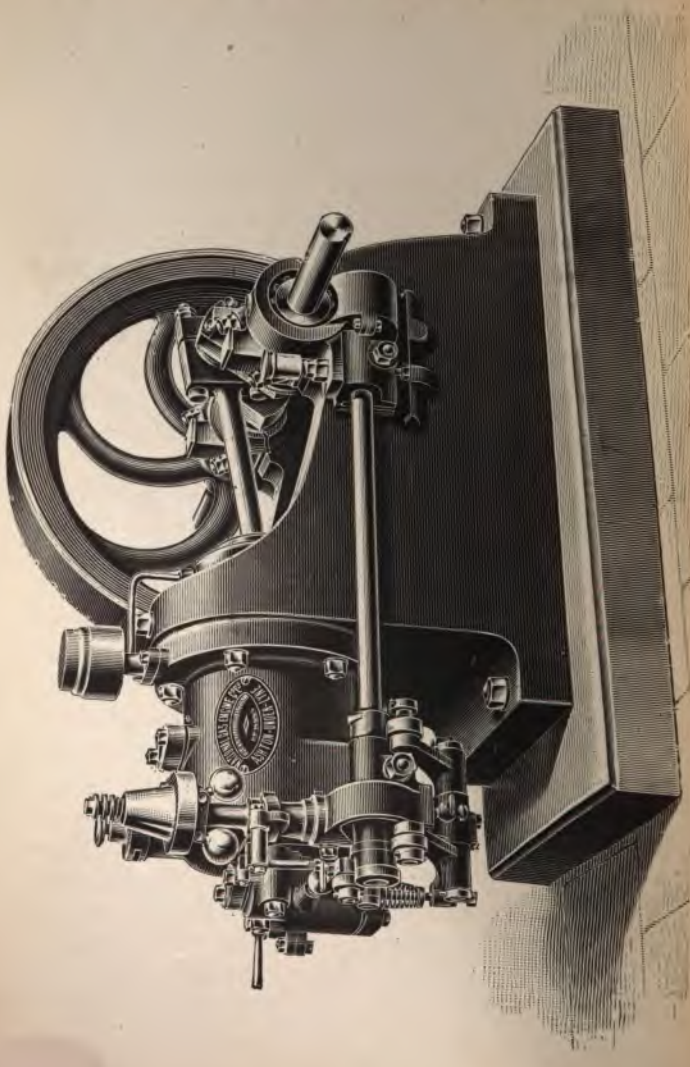


FIG. 92.—NATIONAL COMPANY'S "J" TYPE GAS-ENGINE.

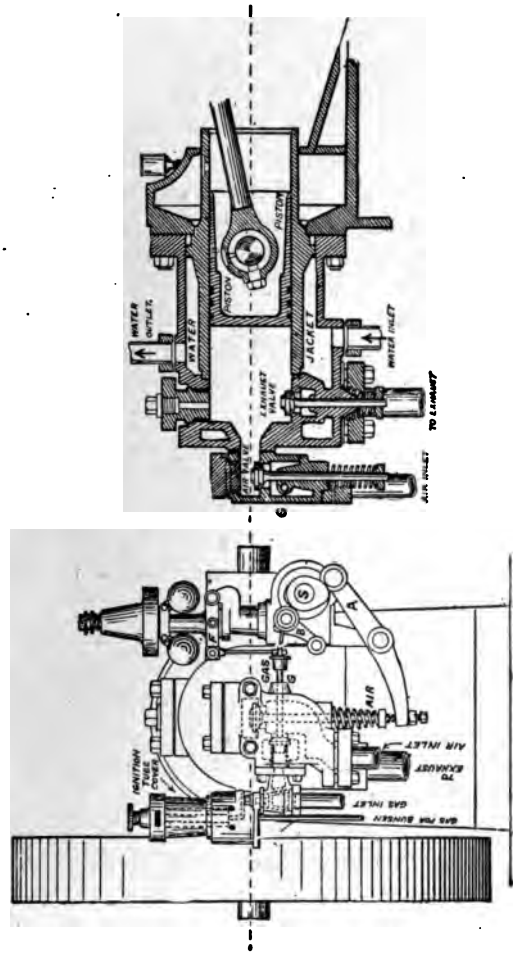


FIG. 100.—END AND SIDE SECTION.

the side section, and the spent gases are forced out of the cylinder by the returning piston.

It will easily be seen that if the compressed charge reaches the red-hot walls of the tube before the crank has "turned the corner," *i.e.*, passed the dead-centre, the crank will be urged in the opposite direction, and the engine reversed. This is "pre-ignition." Also, if the mixture does not quite reach the tube, an explosion will be missed—or a "misfire" occurs. Both these troubles are occasionally met with. In the larger engines a fourth valve—the ignition or timing valve—is fitted, which opens communication between the tube and the cylinder at the proper position during the stroke, and then only.

The temperature of the interior of the cylinder will obviously soon become very high, so high as to render it impossible to work. Hence a hollow space is provided round the cylinder in which water is constantly circulating, and by which the temperature is kept down. This is the water-jacket. The normal temperature of the cylinder is then such as just to allow the hand to be placed on the outside of the jacket.

Governing is effected in the following manner: The gas-valve rod, G, is moved to the left by the arm, B, by the intermediation of the metal piece suspended from the governor-arm, F. When the speed increases, the governor-balls describes a wider arc and draw up the arm, F. In this case the arm, B, does not reach G, which is, therefore, unmoved. During this cycle, therefore, the cylinder receives air only, and no explosion is caused.

The engine is not coupled up to the gas supply

direct. If this were done, the intermittent "sucking" of the gas would render neighbouring gaslights unsteady. A large, shallow iron box, with an india-rubber bottom, is, therefore, provided as an "anti-fluctuator," and to this the gas main is connected. The engine, in its turn, is connected to the other side of the box. This forms a storage chamber, and when the engine draws in its charge, the flexible bottom collapses, thus preserving the steadiness of the supply.

To prevent the noise naturally caused by the suction of a considerable quantity of air, an iron box, with a grating in front, is provided, and inside this box a quantity of cocoa-nut matting is placed. The air entering this "silencer" is thus deprived of any solid impurities and the noise deadened. The air pases from this to the engine. A similar iron box is provided for the exhaust into which the spent gases discharge before passing into the outer air. With large engines a jet of water is sprayed into this exhaust silencer, so as to cool the gases and condense the steam—one of the products of the explosion.

An oil-engine is a convenient prime mover where neither electricity nor gas is available. The arrangements are mainly the same as in the gas-engine, with the exception that instead of gas a quantity of oil vapour is drawn into the cylinder with the proper amount of air. In the oil-engines made by the National Company, a lamp is used to start vaporisation; but when the engine is running, the heat of explosion is sufficient to keep the vaporiser at its proper temperature. A special form of ignition-tube

is arranged within the vaporiser, and its temperature is maintained by a patented device, which also ensures that the ignition shall take place at the proper time. A small pump injects the required quantity of oil into the vaporiser in each cycle of operations, and the governor adjusts the stroke of this pump to suit the load

PARTICULARS OF MR. GUILBERT PITMAN'S LATEST TECHNICAL PUBLICATIONS WILL BE FOUND OVERLEAF.

85, FLEET ST., LONDON, E C.

Electric Bells, ... Indicators & Aerial Lines.

By UMBERTO ZEDA.

Translated from the original Italian and revised by S. R. BOTTONE.

128 Crown 8vo pages. 109 Illustrations.
Price, in Cloth, 2/- net; post free, 2/2.

The author has given great prominence to those points in which the Italians have introduced novelties and improvements in the usual ways of working, and for this reason alone it is believed that this work will prove of much interest and real practical value.

CONTENTS.

CHAPTER I.—Description of apparatus—How an electric bell works—Installation of bell—Electro-magnet—Armature—Gongs—Explanation of circuit—Single stroke bell—Continuous ringing bells—Alarm bells—Signalling bells—Indicating bells—Indicators—Their action—Drop indicators—Self-replacing, pendulum, ship, and other indicators—Bell pushes and other contacts—Burglar alarms—Automatic contacts.

CHAPTER II.—Batteries: their origin and object—Electric current—E.M.F.—The volt—Voltaic cell—Potential—Resistance—Conductivity—Ohm's Law—Ampere—Circuits—Leclanché cell—Sal ammoniac—Creeping—Agglomerate cell—Dry cells—Amalgamation—Restoring Leclanché cell.

CHAPTER III.—Setting up electric bells—Wiring—Leakage—Positive or negative, how ascertained—Fixing pushes—Tubing—Earth return—Relays—Burglar alarms—Connections and diagrams of wiring electric bells and indicators, from the simple front door bell to the complicated connections for a complete installation of a large modern hotel.

CHAPTER IV.—Some useful electrical devices—Method of attracting attention to a supposed corpse in hospitals—*Roulettes*—Heat indicators for stoves and incubators—Fire alarms—Electric locks operated from a distance—Signals indicating change in level of water in tanks and rivers—Use of electric light mains for bell installations—Resistances.

CHAPTER V.—Aerial lines for bells and telephones—Supports and insulators—Protection from lightning—Wires—Conductivity—Joining wires—Straining—Distance between supports—Lightning arresters.

"The important part which Electricity plays in the industrial progress of the world is now fully recognised—the future of Electricity is absolutely beyond the Realms of Imagination."

Professor J. A. FLEMING.

BOTTONE'S

ELECTRICAL ENGINEERING FOR STUDENTS.

Specially written in crisp, attractive, pictorial language, so that anyone can understand it, with full constructional details of all the appliances used, in order to meet the requirements of Home Students in Electrical Engineering, and also to fulfil the conditions of the City and Guilds of London Institute's Examinations.

By S. R. BOTTONE.

Author of "Amateur Electrician's Workshop," "Talking Machines and Records," "Ignition Devices for Petrol Motors," etc., etc.

This up-to-date, accurate, and comprehensive work is the most important book on Electrical Engineering ever issued at the price.

There are many students who, desirous of acquiring a practical knowledge of electrical work, find themselves hampered by their inability to see and to make the instruments of which they read in text-books. Many are precluded by circumstances of locality from availing themselves of the advantages presented by the Polytechnic Institutes; and some cannot attend these owing to the hours of attendance being inconvenient or impossible. This work is intended for the benefit of these, as well as for the general reader. In every case each step made in theoretical knowledge is illustrated by simple experiments performed with home-made apparatus, the construction of which, from specially prepared working-drawings, forms a unique feature of the book, and will enable the enthusiastic student to make and to understand the most useful pieces of apparatus employed by electrical engineers as well as if he had workshop training and experimental instruction.

PART I.—Magnetism and Magnetic Apparatus.

PART II.—Static Electrical Instruments, including a detailed illustrated description of the construction of a Wimshurst Electrical Machine specially for X-Ray work.

Crown 8vo. Strongly bound in Cloth. 49 Illustrations. 160 pages. Price 2/- net.

MODERN DYNAMOS AND BATTERIES. . .

FOR AMATEURS AND STUDENTS.

With Full Constructional Details and Working Drawings for Making Dynamos, Motors, Cells, Batteries, Measuring Instruments and other Accessories, together with Carefully Selected Questions enabling the Student to Test his Knowledge from time to time.

Specially written to meet the requirements of the City and Guilds of London Institute's Examinations.

By S. R. BOTTONE.

Cr. 8vo, 192 pages, 134 Illustrations, Cloth, 2/6 net; post free, 2/9.

SECTIONS FOR THE PRACTICAL AMATEUR.

HOW TO MAKE A SIMPLE FORM OF CELL.—HOW TO MAKE A DANIELL CELL.—HOW TO MAKE A BUNSEN CELL.—HOW TO MAKE A CHROMIC ACID BATTERY.—HOW TO MAKE A DRY CELL.—HOW TO MAKE A SIMPLE AMMETER.—HOW TO MAKE A COPPER VOLTAMETER.—HOW TO MAKE A REPULSION FORM OF AMMETER.—HOW TO MAKE A SOLENOIDAL VOLTMETER.—HOW TO MAKE A SOLENOIDAL AMMETER.—HOW TO MAKE A MAGNETO-DYNAMO.—HOW TO MAKE A GALVANOMETER.—HOW TO MAKE A MODEL DIRECTION INDICATOR.—HOW TO MAKE A PATTERN FOR CASTING.—HOW TO MAKE A 35-VOLT OVERTYPE DRUM DYNAMO.

*** Special attention has been given to the limitations imposed upon the average amateur by the want of elaborate tools; so that nearly all the apparatus and machines described can be made, by anyone possessed of a little perseverance, with the tools usually found in the amateur's home.

PRESS NOTICES.

"Mr. Guilbert Pitman is rendering valuable service to a very large and ever-widening constituency by his technical publications. They are produced with the utmost care, are all usefully indexed, helpfully illustrated, and are the work of men who are recognized as experts on the subjects they handle. One of the latest of these valuable books is 'Modern Dynamos and Batteries,' and the author has done his work very thoroughly."—*Blackburn Weekly Telegraph.*

"The author has treated the subject in a manner that will commend itself for simplicity and accuracy."—*Newcastle Daily Chronicle.*

"Unquestionably a very useful work"—*Weekly Budget.*

"Will prove most valuable to the amateur electrician."

London Evening News.

Turning for Beginners.

By JAMES LUKIN, B.A., . . .

Author of "Possibilities of Small Lathes," "Simple Decorative Lathe Work," etc., etc.

Cr. 8vo. Strongly Bound in Cloth. Price 1/6 net; post free, 1/8.

An excellent general treatise on the fascinating art of turning in wood and metal. The book is fully illustrated and crammed full of excellent advice, not only on the question of how to correctly manipulate the various tools, but also contains much valuable information with regard to choice of a lathe, and the accessories that are likely to be required by the novice. Many pounds may be saved in the purchase of a lathe by consulting this work.

There are 128 pages and 130 Illustrations, including Fourteen Plates of Examples of Turned Lattice-Work, Spindles, Vases, Plaques, etc.

PRESS OPINIONS.

"Crammed full of excellent advice."—*London Evening News.*

"Very clear and concise, and contains a mine of information. 'Beginners' need not be the only persons to profit by it."
London Morning Leader.

"Will be appreciated by amateurs."—*American Machinist.*

"Should prove of real service to amateurs, while professional craftsmen as well will derive many valuable hints."—*Aberdeen Free Press.*

"This dainty book should appeal to a very wide circle of young men. It is indeed a wonderful work."—*Dundee Courier.*

"The technical text-books published by Mr. Guilbert Pitman are deservedly popular, for they are compiled on the right lines."
Weekly Budget.

"Lavishly illustrated, interesting, and concise."—*Scotsman.*

"Interesting, clear, and practical."—*Electricity.*

"The examples of Egyptian lattice-work, etc., will be very helpful not only to the beginner, but to the advanced lathe worker."
Irish Times.

LUKIN'S

Possibilities of Small Lathes.

A THOROUGHLY PRACTICAL AND UP-TO-DATE TREATISE UPON MODERN LATHES . . . OF SMALL DIMENSIONS. . . .

Profusely Illustrated. Cloth, 1/6 net; post free, 1/8.

SYNOPSIS OF CONTENTS:—

The Cheap £10 Lathe; Examples of a few Simple Articles; Designing; Home-Made Tools; Ovals or Ellipses for Small Frames; Spiral Work; Square and Triangular Pedestals; Swinging or Balanced Overhead; Details and Further Particulars of Overhead; Cone Plate or Boring Collar; Pipe Chucks; Screw Chasing; Dumbleton's Apparatus; Ornamental Drilling; Metal Work; Chucks; Home-Made Chucks and Drills; New Forms of Home-Made Overhead; Principle of Cutting-Tools; Cutter-Bars; Gauges, Squares, and other Measuring Instruments; Simple Lessons in Turning.

PRESS OPINIONS.

"The Author is a well-known amateur mechanic, and his instructions are always thoroughly practical. The book is an excellent one, and will appeal to many of our readers."—*The Scientific American.*

"There must be many amateur users of small lathes to whom this little book will bring some pleasant surprises."
Manchester Guardian.

"The subject is very attractively treated, and forms a most interesting revelation of the astonishing capabilities of a simple lathe."
Blackburn Telegraph.

"Well-written, useful, and intensely interesting."
Midland Herald.

'Contains plenty of practical hints."—*American Machinist.*

"This is a handy little book of absorbing interest to the amateur mechanic."—*Newcastle Daily Leader.*

BOTTONE'S

IGNITION DEVICES

FOR GAS AND PETROL MOTORS.

With a Chapter treating specially of

STRUCTURAL DETAILS, CHOICE, AND MANAGEMENT OF AUTOMOBILES.

FULLY ILLUSTRATED.

Cloth, 2/6 net; post free, 2/8.

COMMENDATIONS FROM WELL-KNOWN PAPERS:—

"Mr. S. R. Bottone's little volume on 'Ignition Devices for Gas and Petrol Motors' will be found very interesting to the amateur who is intelligent enough to wish to know something about the engine which drives his launch, his motor-car, or his bicycle. The preliminary section is devoted to a useful disquisition on the choice and management of automobiles, with well-arranged information as to their structural details. This chapter is alone worth the half-crown demanded for this book."—From the *Westminster Gazette.*

"Of such a character as to make the work almost indispensable."—From the *Manchester Courier.*

"Another book that should be added to the library."
From the *Review of Reviews.*

"This little handbook will be found invaluable to all amateur electricians and automobilists interested in spark coils and their workings, as well as in the other parts of an electric ignition system. The Author is a practical man of experience One of the most interesting descriptions in the book is that of a combination jump spark coil and dynamo of his own invention. Instructions are given for making both primary and secondary spark coils. The theory of their working is also clearly explained. An introductory chapter on the automobile is of considerable interest."—From the *Scientific American.*

Talking Machines and Records. . ❧ *How Made and Used.*

By S. R. BOTTONE.

90 Pages. Crown 8vo. Fully Illustrated.
Price, strongly bound in Cloth, 1/6 net.
. . . Post free, 1/8. . . .

The information conveyed in this book, by word and picture, will enable anyone to form an intelligent conception of the principles of the talking machine, and to make a record of any sound—be it noise or music, speech or howl—and to reproduce the same at the will of the operator.

Full and clear directions, accompanied by carefully-prepared drawings, are given for making a simple but efficient and complete instrument. The historical portion is also fully dealt with, and the original instruments of Kratzenstein, Kempelen, Willis, and Scott, illustrated and described.

"Mr. S. R. Bottone's handbook on 'Talking Machines and Records,' just published by Guilbert Pitman, is an excellent *résumé* of the *rationale* of the phonograph and gramophone, with full instructions for making a simple phonograph and the production of records and blanks. Everything is explained in the lucid and practical manner which always characterizes our old correspondent's communications."—*English Mechanic.*

AMATEUR'S COMPANION TO THE WORKSHOP.

Being a collection of practical Articles and Suggestions for the use of Amateur Workers, including detailed Instructions for the Home Construction of Electrical and other Models and Apparatus, forming entertaining and useful recreations for spare hours.

"The bow cannot possibly stand always bent,
Nor can human nature subsist without recreation."
CERVANTES.

By

S. R. BOTTONE, J. H. WOOLFITT,
R. A. R. BENNETT, M.A., F. A. DRAPER,
THE EDITOR OF "THE ENGINEERING WORLD,"
AND OTHERS.

Amateurs will find this book instrumental in furnishing fresh and useful suggestions to be carried out in the workshop, and more particularly in providing suitable models and apparatus to be made with special reference to their ability to yield satisfactory results in the hands of the junior electrician; and to this end the minutest details are given as to the way to set about their construction, which in no case is beyond the powers of the ordinary amateur.

Copiously Illustrated by carefully prepared Working Drawings. . .

AMONG THE VARIOUS ARTICLES ARE:—

SMALL ELECTRO-MOTORS.
A CAMERA OBSCURA.
AN AMERICAN AERIAL YACHT.
AN ELECTRIC-SHOCKING MACHINE.
MODEL TELEGRAPHIC INSTRUMENTS.
STORAGE BATTERIES.
ELECTROTYPING.
AN ELECTRIC-BELL INDICATOR.
A SPARK-COIL AND CONDENSER.
TWO KINDS OF ELECTRICAL MACHINES. *Etc., etc.*

Cr. 8vo, strongly bound in cloth, price **1/6** net; post free, **1/8**

IF YOU HAVE ANY SPARE TIME,

This book will tell you how to use it.

YOUR SPARE EVENINGS.

HOW do you intend to spend them?

The three or four hours between early candle-light and bed-time are among the best of the twenty-four.

Two or three evenings a week for two or three months will work wonders in the enrichment of the Home.

Suburban Homes:

THEIR ACCESSORIES AND EMBELLISHMENT.

By J. H. WOOLFITT,

Sometime Editor of "Amateur Work."

This book is published in response to a widespread demand for a really practical work of this character. It is filled with detailed information, valuable suggestions, and helpful hints concerning the making of simple, yet artistic, and useful additions to one's house, planned with a view toward fitness, harmony, and comfort.

ELABORATE WORKING DRAWINGS . . FORM A SPECIAL FEATURE. . .

Among the special topics treated are:—

A Semi-Rustic Porch.
A "Queen Anne" Porch.
A Novel Fitment for the Hall.
A Design for a Bureau.
The Fireplace:—
I. In Winter—Revolving Settees and Cosy Corner, with Bookshelves above. II. In Summer—A Daffodil Fretwork Screen and Cupboard.
A Dresser-Cabinet for the Kitchen.
A Music-Seat for the Drawing-room.
A useful Shed for the Garden. *Etc., etc.*

Cr. 8vo, strongly bound in cloth, price 1/6 net; post free, 1/8.

The Pleasant Art of Photography Made Easy.

A Practical Work, pleasantly written, forming an Easy Guide for the Beginner in Camera Work.

This book is an attempt to encourage the would-be photographer by pointing out to him that photography is not a difficult and need not be an expensive hobby. The author gives the necessary instruction in a clear and simple manner, and steers clear of all ambiguities and non-essentials.

CONTENTS.

Introductory—A few words about Pinhole Photography—Choice of Apparatus—Plates—Developer and Fixer—Paper—Toning—The Dark Room—Washing—Lamps—Management of the Camera—Choosing a View—Making the Exposure—Developing—Mishaps—Drying the Plate—Printing—Toning—Mounting the Print—Other Apparatus—How to Make a Permanent Dark Room—Choice of an Illuminant—Weights and Measures—Optics and Light—Focusing—Instantaneous Photographs—What you cannot do—What you may do—Portraiture—Interiors—Intensifying—Reducing—Vignetting—Lantern Slides—Colouring Lantern Slides—Enlarging—Index.

PRESS OPINIONS, etc.

"Conveys instruction in a very clear and simple manner."

Builders' Reporter.

Mr. S. R. BOTTONE, the eminent scientist, says:—"The chapter on lenses is excellent."

An M.D., writing from the Middlesex Hospital, says:—"The best elementary book I know."

"The author discourses on his theme in a pleasant, easy-going way, and manages to convey technical instruction without being dull."—*British Journal of Photography.*

"Of unlimited value to the beginner and those who are thinking of taking up the subject. After carefully studying its pages I can confidently recommend it to one and all."—*Hull Times.*

"The author does not frighten his readers with pages of formulæ; he does not ruin them by advising the purchase of the hundred and one up-to-date adjuncts; and yet he covers the whole ground."

English Mechanic.

"We find it just the thing to put into the hands of amateurs. Pleasantly written, it progresses gradually from one step to another, pointing out difficulties, and in plain language telling the beginner how to overcome them. It is a clear and concise guide to the simpler branches of photography."—*Leisure Hour.*

Another M.D. writes:—"I think it is just the thing for the beginner; the chapter on lenses is excellent, and I also like the way the tyro is gradually led up to better work, and also to make his own dark room. It seems to me just the very book I should have hailed with delight when I first commenced photography."

Crown 8vo, 120 pages. Japon Cover, price 1s. net; post free, 1s. 1d. Art Linen, Stiff Boards, 1s. 6d. net; post free, 1s. 8d.

Engineering World

and

Amateur Carpenter & Electrician.

2d. Monthly; post free, 2½d. Yearly, 2/6 post free to any part of the world.

The aim of the ENGINEERING WORLD is, *inter alia*, to supply practical and interesting articles, accompanied by carefully-prepared working drawings, on the various subjects coming within the scope of the journal, written by the foremost writers of the day.

The following are the titles of some of the special articles that have appeared in recent issues, in addition to the serial articles on Electrical Engineering, Turning, Ornamental Lathe-work, Telephones, Telegraph Secondary Cell Installations, Dynamos, Batteries, etc.:—

An American Aerial Yacht.—A Design for a Bureau.—How to Make a Phono-Motor.—An Electric Shocking Machine.—A Novel Fitment for the Hall.—A Camera Obscura.—How to Make a Four-Volt Accumulator.—A Dresser-Cabinet for the Kitchen.—How to Make a Wimshurst Machine.—A Simple and Powerful Box-Kite.—A Semi-Rustic Porch.—How to Make Telegraphic Instruments and Dry Cells.—Small Electro-Motors, and how to Make Them.—How to Make Electrotypes.—How to Make an Induction Coil.—How to Make a Plate Electrical Machine.—How to Make an Ammeter.—The Revolving Bookcase: How to Construct it.—A Cylinder Electrical Machine.

Vol. I., comprising Nos. 1 to 12.
Vol. II. ,, Nos. 13 to 24.
Vol. III. ,, Nos. 25 to 36.
Vol. IV. ,, Nos 37 to 48.

Handsomely bound, 3/6 each net.

All Nos. and Vols. are in stock.

"The Engineering World" may be ordered from any Newsagent or Bookstall.

Shorthand World and Typist.

32 pages. Monthly. Price 2d.; post free, 3d. Yearly, 3/- post free to any part of the world.

BUSINESS SECTION (in ordinary Letterpress).

The matter for the Shorthand-typist, contributed by writers of reputation and experience, is full of suggestive and helpful interpretation, and includes practical articles on Typewriters and their Development, Duplicating Devices, Card Indexes, Systems of Filing, Desks and Cabinets, Ribbons, Pads, and Carbons, Press-Copying, Book-keeping and Loose-leaf Systems, Billing Machines, Form and Style, the Correct Use of Words, Punctuation for Typists, Forms of Addresses and Abbreviations, How to Prepare Matter for the Press and Correct Proofs, and to Write Advertisements—in fact, everything a Shorthand-typist ought to know to make advancement a certainty.

SHORTHAND SECTION (in Pitman's Shorthand).

The Shorthand characters—clear, bold, and legible, divided into three grades, Easy, Medium, and Advanced—at once excite attention and admiration, and embrace Short Stories, Serial Tales, Interesting Sketches for Home Reading, and Humorous Items. Also articles on How to Get Speed and other matters of interest to the Shorthand student are treated in an attractive manner. In short, this unique magazine contains abundance of incident, anecdote, and help, and will afford many a pleasant hour to the general reader as well as to the Stenographer, Typist, or those engaged in business.

"The Shorthand World" may be ordered from any Newsagent or Bookstall.

THE NEW YORK PUBLIC LIBRARY
REFERENCE DEPARTMENT

This book is under no circumstances to be taken from the Building

form 410